Exploring the smartwatch as a tool for medical adherence

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A thesis submitted in fulfilment of the requirements for the degree of Master of Science in the Department of Informatics and Media

June 2015
Declaration of Authorship

I, Akash Shrivastava, declare that this thesis titled, 'Exploring the smartwatch as a tool for medical adherence' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a masters degree at this University.

- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.

- Where I have consulted the published work of others, this is always clearly attributed.

- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.

- I have acknowledged all main sources of help.

Signed: Akash Shrivastava

Date: 28th May 2015
Abstract

Department of Informatics and Media

Master of Science

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by Akash Shrivastava

Keywords: Adherence, Compliance, Smart watch, Wearable technology

Adherence to medication is generally described as a huge problem in the health care system. The term adherence is generally preferred by many health care providers as the word ‘compliance’ describes a patient who is passively taking medication as advised/ordered by the doctor. This thesis goes in depth in identifying the problems faced to achieve maximum adherence to medication and the important factors contributing to it. The objective is to come up with an alternative approach to help improve medical adherence using a smart watch based application that reminds patients to consume their medicines in a timely fashion. It addresses precisely which medication to take and in what quantity. This form of reporting and alerting is believed to achieve higher levels of adherence based on grounded theory. Shedding light on the methodologies used while clearly identifies the assumptions and limitations such a system can have...
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<table>
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<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>IoT</td>
<td>Internet Of Things</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>HIV</td>
<td>Human Immunodeficiency Virus</td>
</tr>
<tr>
<td>NSAID</td>
<td>Nonsteroidal Anti-Inflammatory Drugs</td>
</tr>
<tr>
<td>SMS</td>
<td>Short Message Service</td>
</tr>
<tr>
<td>ADR</td>
<td>Action Design Research</td>
</tr>
<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
</tr>
<tr>
<td>UI</td>
<td>User Interface</td>
</tr>
<tr>
<td>UX</td>
<td>User Experience</td>
</tr>
<tr>
<td>BIE</td>
<td>Building Intervention Evaluation</td>
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<tr>
<td>APK</td>
<td>Android Application Package</td>
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I dedicate my thesis to my father who inspired me to reach new heights, who enabled me to be where I am today, without him it wouldn’t have been possible. His story is what inspired me to have this subject as my thesis.

I miss him dearly.
Chapter 1

Introduction

1.1 Identifying the problem

“Medicines do not work on people who do not take them” said by former U.S Surgeon General. Satisfactory adherence can only be achieved when patients take their medicines religiously. This varies from case to case as in some therapies minimum adherence as required by the doctors is 80% but in some severe cases such as patients with HIV are required to be 95% compliant to the medication [2].

There are various reasons why adherence falls after the initial prescription to medication which includes lack of belief in the treatment, side effects due to the medication, the presence of psychological problems such as depression, lack of patient’s insight into the treatment and perhaps the most significant reason is lack of proper communication between the patient and the health care provider. Most regimens are usually not explained very well during or after the diagnosis, this attributes to poor communication and underestimated importance to follow the regimen. Unfortunately maximum adherence is only said to be achieved in clinical trials or highly controlled environments.

Patients with a simple dose i.e. one pill a day display maximum adherence with some external interventions or reminders from the health care provider, hence adherence rate can be seen inversely proportional to the number of doses. It is
found to drop drastically when the consumption pattern gets complex such as a few pills twice a day etc. In a study done by Claxton et al, adherence can get as low as 30% when the patients have to take pills 4 times a day [3].

As adherence in itself is a broad term, it is defined differently as some health-care providers also take into account the time of the medication taken by the patient. This adds to the complexity of measuring adherence as measuring the time of the medication can be impossible unless it is within a controlled environment, even attempts of measuring it can be deemed intrusive and frustrating.

Poor adherence can only lead to the worsening of the disease, and in some severe cases death. This only causes an increase in costs and resources taken up by the hospitals etc. As patients who adhere poorly to their drugs tend to visit the hospitals more often to seek treatment, as mentioned by Dr. Lars [2] out of all the admissions to hospitals about 30% of them can be account for poor adherence. Cases that cause the lapse of disease and worsening end up costing more to the health care system, doubling its work. As a result it becomes extremely important to identify and tackle the problem in the most effective way.

1.2 The Internet Of Things

The easiest way to define the internet of things would be when our milk cartons will remind us that its running low and its time to buy some more milk. A light vehicle (cars and trucks) is said to be shipped with 60-100 sensors onboard. As not just cars, but entire homes, phones and other miscellaneous electronic devices are getting smarter, we are moving from an information age to a connected age at an exponential pace. Technology, business and the ubiquitous information are transforming society everyday and the amount of data that this change is bringing is of meteoric proportions. It is said that more that 212 billion devices will be part of the internet of things by 2020 [4].
There is a colossal influx of devices in the market today all aiming to solve problems in all departments. Each device will be fitted with sensors that are then communicating to one another via a computer just like a nodal network. Mass data being clocked by tiny sensors and devices usually either being handheld or a wearable device. Placing data on a network, connecting them to the internet enabling data processing and analytics for better decision making. This enables high levels of productivity while saving money. For instance, the service that is responsible to pick the garbage from all the bins around the city need not visit bin after bin. Tiny sensors will communicate and alert the personnel when the bin gets full automatically.

These technologies are not just part of a niche, they are creeping into all industries such as the automotive industry with self driving cars, home automation is being made possible, health industry is transforming with bio wearables and food sensors. In the 2013 CES (consumer electronics show) Hapilabs made headlines that made a fork that calculates the total amount of calories one is eating and helps one track your input of total calories. The company behind the smart watch pebble made debut after the largest kickstarter ever. They launched the Pebble flex, a smart watch that lasted for more than 7 days on an single charge, synced with ones phone giving that person notification and other information regarding incoming calls and upcoming calendar schedule. The watch is platform independent of a phone and can be paired with any phone giving it huge traction in the market.

It is due to the internet of things innovative solutions are being brought to life everyday. Tapping into the wearable technology such as a fitbit or a smart watch and using them to address the problem with medical adherence is one solution. A different approach taken by another company, Proteus is working on developing
a pill that goes into the body and measures how well the body is responding to a medical regimen. Once the data goes into the cloud it is then monitored by doctors and caregivers.

Vision mobile [4] estimated that most IoT applications will use data that already exists today rather than newly create from various sensors. Value or understanding of that data is created when you can successfully mine it and make sense of it. As time progresses solutions that will make sense of this data will get cheaper. Allowing that technology to prevail, so new hardware won’t be necessary to build, test or maintain. According to Vision mobile the percentage of current mobile developers that are preparing their line of products and service for the IoT is around 53%, predicting a huge change in the coming years.

![THE NUMBER OF IOT DEVELOPERS 2014–2020](image)

**Figure 1.2:** Number of developers in millions working on IoT

In the above section we discussed how making sense of the data is crucial and will be the driver of IoT, data is everything. Data is being used and shared between devices and across platforms. As data and all the devices connected will only grow as time goes on, the possibilities and opportunities for innovation will get this growth on a chain reaction.

Lars Osterberg proposed [2] in his paper that new innovative measures have to be taken in order to maximize adherence such as digital assistants or adaptive cell phone reminders or other programmable devices. He concluded by stating more research and development in this area will reveal the possibilities that can be implemented.
1.2.1 Smart Watches and IoT

Just as 2010 and 2011 were said to be the years of the smartphone, 2015 is well within the shout of being the year of wearable technology. Wearable computing is what will creep into most other technologies, just as we see mobile phones being used in the photography, film making industry or the millions of applications through the lenses of augmented reality.

Developers are going to pop all over the place, as we see in the current market. Estimated number of developers only in the mobile industry is around 5.5 million [5]. Proving a really niche business growing to be successful in the mobile industry. Companies like Whatsapp, Nest, Snapchat have created multi-billion dollar industries that were really not imagined before.

Nest allows consumers to control their thermostat using their smartphones which can also be accessed by one’s computer from anywhere in the world. Whatsapp is a messaging application that was made available on all possible platforms from a desktop client to mobile device. Seeing opportunities in the messaging business, making messaging free of charge gave whatsapp a boost in growth across the world. In October 2014, Whatsapp was bought by Facebook. Inc for a whopping $19 billion. Even though picture sharing was nothing new, Snapchat introduced sending messages that could not be saved specifically pictures and videos. As of today they report to have 1 billion pictures and videos sent to one another every day. All the above examples saw their best opportunity in the consumer market. Eventually this will happen to the wearable industry as well [5]. A surge of wearable devices are swarming the market and there are no signs of slowing down.

We are already starting to see companies being based on watch faces. Studio Extreme a mobile developer makes watch faces for Android wear, Google’s new watch platform. Developers just designing watch faces for smartwatches catering to a really niche audience today, challenging physical watch manufacturers. Vision mobile predicts there will eventually be a war between platforms that will do the
best job at empowering developers and connecting them with their target audience. Those that succeed will eventually dominate.

![Figure 1.3: Internet Of Things Trends](image)

Most developers are trying to create their own verticals taking a sliver from the pie. They report 35% of developers have current resources devoted to the development for the smart watch and 75% of them are planning for future development. The rest of the focus was distributed across different industries such as home automation, smart car, medical industry and even retail.

### 1.2.2 Android Wear, a Platform

This section goes into depth of choosing a platform for a smart watch. The idea of a smart watch, a watch that shows ones email, text messages and allows one to reply via voice is a new one. It sits on top of existing functionalities of ones phone as an overlay of notifications with constant synchronization with the smartphone.

Watches being devices that show more than just time is an old idea, one tracing back to as far as 1994. Timex introduced a linux based watch that enabled users to add schedules and contacts to their watch. Smart watches had never been introduced to the consumer market, and the times they were they were always a
Chapter 1. Introduction

standalone product rather than a platform. The market is usually more accepting when there is margin for improvement or development. Google opened this possibility last year with the introduction of Android Wear. Android wear is the underlying platform of the smartwatch design, it is open source. It allows the possibility for anyone to be a smart watch vendor who can build the hardware around the platform. Launched during Google I/O 2014, the yearly conference Google has on all things Google. They also announced Google fit, a set of APIs that made use of data from all the sensors in their phones and watch to generate real value. The condition of it being open source opens up millions of possibilities not just on the hardware side but also software. As seen with IoT the same opportunity is given to the smartwatch platform.

There is a surge of interest from technology giants such as Apple, Nike, Samsung and others who are making wearable technology to bring it to everyday consumers.

As of today, Android Wear has seen the most traction by consumers and developers. It provides an easy motivation to develop for a platform that is open, allowing freedom in terms of development as compared to other closed platforms that the competition has to offer.
1.3 Aim Of The Study

The purpose of this study is to understand the consumption pattern of medicines in patients while identifying what lowers adherence levels and what are the measure that can be taken to improve it. In an Interview with Dr. Johan Häggström, a Hematologist at Kalmar hospital working within Oncology pointed out that forgetfulness of prescribed medication doesn’t just happen when patients start to get senile. It can very well happen to people in their 20s due to various reasons.

Forgetting to take ones medication is not just blamed on diminishing of cognitive abilities but can be attributed to many reasons discussed in the chapters ahead. Reasons range from lack of trust in the medical regimen to conscious decision to not consume the medication or even lack of proper understanding of the treatment itself. As this can have serious negative effects to a person’s well being the motivation to develop a tool to address this became clear.

This study aims to develop an application that can be installed on a wearable device such as a smart watch to ease the communication process between the medical practitioners and patients. The use of electronic reminders and other pager systems has been deeply researched on and have shown positive results to improve adherence [6]. This practice is based on the principles of behavioral learning theory. The theory includes short message pings either over a pager or via SMS. Studies have shown short-term improvement in adherence but the long-term implications are yet unclear referred in Appendix A. The theory suggests additional layers of interventions such as phone calls from doctors. Lars Osterberg, MD who is a clinical associate professor at Stanford University suggested repeated reminders (about every 5 minutes) right after the patient was notified to take the medication as a type of added intervention.

This study will attempt to tackle some of the communication problems that people undergoing treatment face. Problems such as difficulties in sorting medication in case there are more than one and allotting, reminding what time to take certain medication or the amount of dosage just adds complications to adherence. An
application will be developed that can be installed on an Android smart watch that will aim to tackle the problems discussed above, a kind of an electronic and highly efficient dosett.

1.4 Research Questions

The ultimate success of the study would be answering some set questions towards the end. With the help of grounded theory and empirical data the following questions are aimed to answer. Given the time span of the research, questions framed were precise and restricted.

- Why does a smart watch improve communication over other devices such as a phone?
- Is a wearable device acceptable to someone who isn’t used to wearing one, receiving daily notification when its time to take ones medication?
- Are there certain situations where the proposed technology cannot be implemented?

We aim to answer the above questions during the duration of this research. The first two questions will be supported from collecting qualitative data from interviews. This will also be supported by finding the latest trends on smart watches and conducting a market study, making it clear why a smart watch is a good device to start with for a project such as this one. Due to the limitation of time, the third question will be answered by pure motivation towards the solution. Qualitative answers gathered during interviews and the literature review will help support the claims made. A study on that scale will yield clear answers if the watch was influencing their adherence patterns.
Chapter 2

Knowledge Base

2.1 Measure of Adherence

Having a good assessment and to accurately measure adherence is crucial to any treatment. Unfortunately, there is a lack of standard within the dealing between a patient and the health care system [7]. Most practices vary and each doctor/clinician has their own way to tackle the problem. Adding to the complexity, change in regimen, dosage, difference between the generic medicines and even communication style can influence the patients behavior and disrupt their regimen.

In an interview with Dr Johan Häggström, a Hematologist specializing with cancer patients reported to have constant problems with his patients not taking their medication. When patients weren’t responding to the medication, it was always the first thought that the patient wasn’t taking their medication. Depending on the seriousness of the condition of his patients, the hospital in Kalmar, Sweden proposed to have regular blood tests not just as part of the treatment but to also measure the presence of chemical substrates of the medicine that was prescribed. This gave the hospital better confidence in the treatment of the patient reinforcing their approach. He believed patients that did not show up for the appointment were most likely having trouble to adhere to the medication.
This methodology though effective and leaves no loopholes in measuring adherence increases the workload in the health care systems. The costs of conducting additional blood tests just to look for core compounds from the prescribed medicine in the blood can be cumbersome as the number of patients increase.

In most acute situations all patients were admitted within the hospital in a highly controlled environment where the hospital could monitor and make sure patients have taken their medicine in a timely manner. This form to measure adherence is called direct observed therapy.

Another form of direct measurement is called measurement of biologic markers in the bloodstream. This form of therapy includes medicines that are intentionally used to be found later in the blood during blood tests. The following are a few indirect practices carried out by most health care providers:

**Patient questionnaire** – This method focusses on the patient-doctor/clinician communication. Patients will be asked to fill out a form with open ended questions, questions that help understand potential side effects and consumption patterns for various drugs. This method is found to be more useful in clinical trials in a controlled setting to receive accurate answers. To add to some disadvantages to this, patients tend to answer as they please leading to incorrect results. This is also influenced if the time duration between patient visits is prolonged.

**Pill count** – This is an easy to perform method to keep track of adherence. The process helps the patient keep each pill into separate compartments that have specified days marked on each pill. This is either done on the packaging or with the help of a dosett. The method is highly objective and gives a clear answer weather a patient has been following their medical regimen. The major disadvantage is when/if the patient truly doesn’t want to take the medication, data manipulation is very easy.

**Rate of prescription refills** – In an interview Dr Åsa Häggström, a Rheumatologist at Kalmar hospital reported to regularly make sure the rate at which her patients were getting more medicines. This gives a very clear idea of the pace
at which patients consume their medicines. In cases such as pain killers, it was crucial to prescribe only for a small duration, as in some cases, she reported cases of patients abusing orally induced tramadol, medication primarily used for joint pains and in some cases migraine. To make sure the method of measurement doesn’t fail, one needs to have a very closed pharmacy system. In Sweden, all medicines are controlled by a central organization called *Apoteket* which keeps in check the distribution of such pills.

**Clinical response** – This is a run-of-the-mill practice by health care practitioners to see the medicine reflect on the patients health. The only way this gives negative results is when a patient is reacting to other medicines. The adherence is based on the patients trust and belief in the diagnosis. Dr. Åsa reported in most cases she has really good communication, her relationship with her patients is based on trust.

This brings up another problem encountered by doctors called *white coat adherence*. It was noted by Dr. Åsa that patients usually tend to become more adherent right before and after a doctor’s appointment.

**Electronic medication monitors** – These methodologies involve the patients being hooked up to medical instruments that track vital compounds in the blood. Though this process is precise it is expensive, making it not a very feasible option for all healthcare systems. It requires the patient to have regular visits to the hospital. During which there is a high degree of patient record and everything is documented, but there is no record if the right medicine was taken and if it was taken with incorrect dosage.

**Patient diaries** – This method of measurement requires the patient to self report and maintain a diary on his/her consumption pattern. Patients that have trouble remembering their regimen are highly benefitted via this method but for patients that do not trust the diagnosis can easily change their diaries to match what is required from the clinicians.
2.2 Patient personas

A lot of research can be found on patients being classified as per their condition and its seriousness. Adherence levels have been said to vary within the type of condition as well, such as kidney failure, diabetes or more severe conditions such as leukemia.

In more chronic conditions adherence levels have been noted to fall disappointingly low after the initial 6 months of treatment [2]. Though there is no standard of adequate amount of adherence this displays a lot of space for improvement. Dr. Johan reported that it was not alright for his patients to miss the dosage for longer than 2 days. Preferred adherence levels are very subjective and can vary from doctor. Given the condition that his patients were suffering from something mild. As the severity rises patients are more likely to get admitted to the hospital in a more controlled environment.

In chronic conditions such as coronary artery disease the patients that were not adherent to cardioprotective medications were at 10% to 40% risk of cardiovascular hospitalizations and roughly 50% to 80% were at a risk of mortality [8, 9].

2.2.1 Age as a factor

Age is generally considered a strong factor with regard to adherence, but the main reason of why age is a factor can be attributed to the weakening of cognitive abilities. Even though age is a strong factor, patient with those suffering from chronic problems are always prone to low levels of adherence irrespective of age. Diminishing of the neurological system, risk towards side effects due to weakening of the immune system and simple effects of senility can all influence low adherence levels [10]. Adherence was a significant problem in people who were older than 75 [11].

Dr Johan reasoned that poor levels of adherence changed with age but it was for different reasons. His patients who were under the age of 35 and suffering from
a chronic problem tend to forget about their medication as they didn’t believe the problem to be as serious as it could be. This reflects on the communication process between the health-care systems, clinicians and the patient. He said, his younger patients wished to get well as soon as possible without taking appropriate measures to improve well-being. No precautions were taken by his younger patients and still went on upon their daily activities without knowing the consequences.

Considering children, to achieve maximum adherence required a child that co-operates with not just the parent but also the care giver that is equally adherent to the child’s regimen. It required maximum dedication and a well established relationship between the child and the parent or the care giver.

His older patients were not as misinformed, patients took their time to understand the dangers and consequence of the diagnosis and treatment. Their reasons for poor adherence was mostly attributed to senility and lack of confidence in the treatment.

In extreme cases of senility, Dr Åsa reported that there were patients that had forgotten to take their medication. She didn’t realize age as a big indicator, stating the fact of forgetting to take a dosage is attributed to other factors. Such as, taking double dosage can cause serious dangers to a patients health. As a doctor specializing in Rheumatology, she is used to prescribing powerful pain killers. Taking the same medicine twice or two different medicines with the same active ingredient is called double dosing. She mentions painkillers come in two kinds nonsteroidal anti-inflammatory drugs (NSAIDs) and acetaminophen which can have damaging effects. Some of the symptoms of overdosing on pain killers include; nausea, vomiting, burning in the throat, fever, dizziness and even bleeding.

2.2.2 Dosage

Treatment of a disease/condition can be difficult, often riddled with many choices to approach a problem. Certain conditions often change, mutate or develop added complications that can make it difficult to treat or even diagnose. It requires a
very through understanding of the situation a patient is in and then approach it in many ways to triangulate the problem. It requires repeated visits to the hospital depending on the complexity of the condition. When dosage is added to more complex regimen only gets harder to follow.

Cramer J et al [3] in a clinical trial study made participants answer a questionnaire regarding their consumption patterns and their reasoning behind forgetting to take a particular dose. 30% of them contributed to forgetfulness and about 27% of them didn’t have any clear reasoning to state. A lot of these numbers can be attributed to doctors with complex regimens and the lack of explanation pertaining to why it is important to take the medication on time [12].

As per Dr. Lars, there was very little importance given to explaining the side-effects of a certain active ingredient. Doctors usually don’t concern themselves with the patients lifestyle which essentially plays a major role into following a regimen. This only indicates a lack of communication and shows a poor therapeutic relationship between care givers and patients.

Dr. Johan reported that the shelf-life of his treatment usually changes depending on the patients response, though advised for most usual situations the shelf-life of a diagnosis is between 1-3 months. As a rheumatologist he had previously changed medication when his patients gave him negative feedback on the treatment, may it be related to the actual problem or the side-effects. In this case he usually made the dosage more complicated to either counter act the side effects, meaning more medicines to take or in other cases the dosage was changed which meant new pills at different times with new limitations. Just a single change to a patients regimen can highly distort the compliance to medication. It can be difficult to adjust to a whole new pattern of consumption. In more senile patients remembering if the medication was taken by themselves can be a challenge, let alone spotting the correct medication.
2.3 Measures to Improve Adherence

In the previous sections we discussed what hinders adherence and just a few factors that contribute to poor adherence. In this part of the chapter we go in depth of what can be done to improve adherence and the dynamics between the health-care system, the patients and the providers.

Shedding light on the relationship between patients and ancillary health staff can change how the patient reacts to a particular regimen. Health care specialists and behavior specialists are specially trained to be understanding towards patients who are unable to keep up with the treatment. Dr. Ása reported that the most important metric in maintaining adherence levels is that the patient always feels comfortable with the specialists during all phases of the treatment.

Dr. Lars discussed the relationship between the provider and the patients. In this relation it became highly important that the medicines be available at all times when the patient is in need. 24 hours pharmacies specifically served this purpose that they keep up with demand at all times.

![Figure 2.1: Patient, provider and health care system dynamics](image)

**Patient to provider relationship** – In this case, patients have very little understanding of the benefits and the side effects of the treatment if any. In many cases, certain drugs should not be consumed along with other substances such as alcohol. Most patients lack the knowledge about the active ingredient in their
medicines. In other cases, patients have poor understanding of how to use the medication. Certain pills are generally dependent when they are taken. Drugs such as Ibuprofen and aspirin on an empty stomach can cause irritation to the stomach lining.

Other drugs such as blood pressure medicines mix up with food so they slowly dissolve through the system to give maximum effect. Most patients lack this knowledge and is often forgotten to be told by the pharmacists.

**Patient to health care system relationship** – In this case lack of communication is the main cause of low adherence. Most often seen when patients are a no show for appointments patients tend to have lower levels of adherence [2]. There might not be a single best reason for this as patients not showing up for their appointments can cause serious downsides. During the interviews, lack of trust in the treatment or the doctor themselves were some of the reasons for poor adherence.

In minority of the cases poor treatment by clinical staff could cause patients to feel less assured. Depending on where the drugs are purchased the high prices on some drugs can also influence people to be less adherent. Health care systems are very different in most countries, countries where the system is unable to supply all people in need with free or subsidized prices takes a huge toll on people in need.

Giving clear instructions and designing simple regimens can help improve adherence greatly. Customized dosage as per the patients wishes can help improve adherence by large numbers.

**Health care system to provider relationship** – Dr. Lars explained that the prices of drugs were a big concern. In an everyday setting most doctors don’t have a great idea on how much the drugs cost, as their job is to tackle and treat the symptoms and the condition. Hospitals play a role in educating doctors the health care side of factors that can affect the treatment.

Poor knowledge of insurance coverage and costs is another problem that varies from country to country. Not all hospitals are well aware of the costs and range
of coverage of health costs. Drugs with the same active ingredient have different names and are marketed under different brands.

Better understanding between the pharmacies and the health care system can help educate all the stakeholders to take the system one step ahead.

2.4 Challenges

In the above section several methods were considered to improve adherence between all the stakeholders. Some challenges are not as trivial, cases where influencing factors are from external sources apart from the treatment.

2.4.1 Severe Chronic Illness

There is a vast difference between patients that are suffering from chronic and acute conditions. Adherence in chronic severely falls as time progresses, even the dosage times are noted to be highly erratic as per the study done by Dunbar [10]. As much as hospitals try to keep adherence levels high by either blood monitoring techniques or other direct interventions, in certain chronic conditions adherence drops due to the condition itself. Conditions that influence psychological aspects of the persons health can cause a snowball effect. In a paper D robin [1] correlates anxiety and depression with adherence. The author concludes patients that are suffering from chronic problems are 3 times more likely to be non adherent when suffering from depression.

In cancer treatment such as chemotherapy most patients are likely to experience mild to severe depression during and after the treatment. Oncologists are specially advised to prescribe strong antidepressants such as norpramin with the active ingredient desipramine. The plethora of medicines in such a treatment are prescribed to control the chain effect of the resultant side effect from one to the other [13].
Above mentioned is just one of many chronic conditions that cause adherence to drop due to the side effects involved. Patients in this case ought to be specially educated on the pitfalls of each drug. The patient was supposed to take 2 doses of the medicine once per day. The graphs shows high variance between the doses and irregularities between the days. As discussed in the above sections, timing to the medication is as important as the dose itself.

### 2.4.2 Psychiatric Illness

Dr Lars mentions psychiatric patients have the most to lose when being non adherent indicating high risk. They were also said to be the most to gain from proper adherence as their treatment can have promising effects. Patients with schizophrenia were reported to have as low as 50% adherence [14, 15] In fact author Lacro concludes that such patients are at extreme risk of rehospitalization in most cases.

Patients with manic depressive illness or bipolar affective disorder had adherence levels around the 35%. A level at which the medication has almost no effect on the patients health. The biggest challenge seen in this case is educating not one but a group of care givers that are in sight of the patient at all times. The constant use of positive reinforcement techniques on the patient have yielded positive results. These techniques involve behavioral training or other support systems. Patients
were required to have trained professionals at a close distance at all times, without which adherence falls drastically.

Dr Lars advised that the proposed application needs to remind patients 5 minutes right after they were supposed to have taken the medication as a foolproof mechanism. In his experience patients answered more faithfully in their reporting and were increasingly aware of their regimen. He also proposed the use of clear and concise graphs on the watch itself reporting where the patients have forgotten to take their medication, this given the fact that they have been truthful. Patients were supposedly quicker to learn and come out more motivated when seeing how poor their adherence when shows in the form of an image such as graphs.

In cases where patient that are physically handicapped have even more trouble regarding compliance to drugs. Care-givers are required to be present at almost all times keeping uncompromising time schedule.

### 2.4.3 Social factors

Although socio-economic factors are not consistently or independently influencing adherence levels, in the developing world patients might be put in a situation with competing priorities. Factors such as low income, lack of social benefits, unstable living conditions, travel distance/costs to closest medical center or even cultural beliefs regarding the illness can shadow the importance of adherence. Factors such as lack of structure in the health care system to uphold patients from all economic backgrounds is a major problem but many researchers have argued that organizational factors contribute a lot more than sociodemographic factors. In studies done by Strzelczyk et al results shows that [16] it were the organizational values such as doctor’s continuous care, time spent understanding the condition, trust and interpersonal style that were more impactful than education level or income.
Chapter 3

Methodology

3.1 Introduction

In this chapter we go in depth into the types of methodologies used during the development of the project. The biggest paradigms in information systems research can be behavioral research and design science. The founding guidelines of design science research and its principles were followed during the course of the entire research. Using those principles new artifacts will be created during the course of the project forming concepts that will in turn contribute to the field. Using the principles from Gregor and Henver [17–19] the initial set of facts gathered before developing the knowledge base was during the relevance cycle.

In this project the primary artifact created is the software application, which is a by product of the research along with key concepts to keep in mind when designing solutions to increase adherence.

The research design followed during the duration of this project resembles an iterative model of Action Design Research. Each stage in the process enables a reflective process for researchers to able to go back a few steps and apply newly uncovered knowledge to their knowledge base.
3.2 Research Design

The diagram above displays the research design and steps carried out as a researcher. It shows that the evaluation of the knowledge base was taken in form of cycles as feedback. All the changes to the knowledge base was accounted for during the process.

Problem formulation - During the first phase of research a more practice ingrained study takes place. To know the initial facts and practices that are being used in the current system. After studying organizations or practices a problem statement is formulated. The proposed research questions first took shape during this stage. Though the research question have been through several iterations this is where the grounds for formulating future questions was established. Conceptualization of the possibility to have a smart watch as a potential solution was established. Already established theory and the literature review provided a firm foundation for further research and potential gain. As provided by Gregor and
Henver [17–19] the partial formulation of \( \Omega \) (omega) and \( \lambda \) (lambda) representing descriptive and perspective knowledge respectively were established. Understanding already established concepts, models, modes of measurement, patters and theories used to study adherence.

A lot of research out there is characterized into specific types of adherence i.e. adherence in HIV patients or patients with kidney function disorder. It became crucial to understand and limit the scope of the project to one particular condition or a general 1000 feet outlook of the problem. Answering questions like; who can the proposed system not be used on?

**Knowledge base** - Considering the limitation on time and resources available, the research was scheduled over the span of few months. Understanding who to interview and what questions to ask to gain deeper understanding of the problem domain was crucial to the project. As the problem domain is one very different from the ones familiar with, understanding the pain points of doctors and the health care system was important. This phase yields a theoretically ingrained artifact that is based on the work contributed by others.

During the second phase, organizing the literature review step by step learning as new concepts were uncovered. In this phase the proposed artifact started developing its shape. Answering questions such as; What does the application need to show? How should the architecture of the application look like to the user? What are the functions that need to be incorporated within the application? Though the theory mentions alpha and beta testing where the end user meets the application, testing was done by researcher itself during the development. Iterations of the design of the application took many changes as it got closer by the final product reflected by the principle of reciprocal shaping. Design on the application was under constant evaluation taking inspiration from previously built applications and Android wear platform guidelines.

**Expert interview** - After the initial setup, certain methodologies to measure and evaluate were made clear. It is at this phase an expert interview was planned, due to the lack of knowledge considering everyday scenarios at the hospital. Dr. Lars,
a professor at Stanford Medical Center who’s interview was inspired during the literature study. His research paper brought deep insight into adherence, factors that cause it, way to measure it and proposed ways to improve it with various intervention tactics etc.

It is important to note that this study could have highly benefitted by interviewing a few patients. People that have trouble remembering their medication or face trouble with practitioner and the health care system could give a new outlook on the problem. Having to interview patients regarding their medication can be sensitive and requires high degree of permissions granted by the patient to be used in this study and thesis. Due to the short span of the project pursuing patients to be interviewed was avoided.

As the amount of literature grew so did the questions that followed, it became imminent that there was more to understand from real world examples. It was at this stage interviews with doctors was planned that formulated more questions mostly based on patients and their preferences from the literature. There was a lot of discussion on age as a factor for lowered adherence, most doctors didn’t really point it to age but attitude towards the treatment or medication. Patients independent of age were likely to forget about their medication due to various reasons noted in chapter 2. Understanding the health care system and the dynamics between the patients and clinicians was crucial, it allowed possibilities to postulate concepts regarding when and how the proposed system will have to act.

_The principle of authentic and concurrent evaluation_ is reflected in the constant feedback loop that feeds the knowledge base after deeper understanding of the domain. This model modified current design science methodologies and concepts borrowed from ADR to make sure the subject domain was well understood and further motivated the proposed system and contributed towards the artifact. It is important to note that no stage is independent of another, that each step overlaps and is continuous while the previous and next step is being completed or planned.

_Reflection and learning_ represents the next step in ADR, this stage involved conscious problem solving based of the theories chosen in the earlier phases. The
design is highly influenced in this phase as the input from the expert interview played a big role in shaping the application and the project as a whole. The methodologies used until now are evaluated in this stage to find out if any valuable result was yielded. Due to the subject domain, having a single round of the expert input wasn’t sufficient and the next stage experts were approached again with further questions regarding the domain. The Feedback loop was a crucial phase during the course of the project, forcing iterations to the theory adapted and initial assumptions made.

The principle of Guided emergence exhibits a sense of immediate change to the design guided by theory. These changes or refinements are influenced during the BIE cycles. Changes such as if the time component of the application was important, how often does the patient need to be reminded the medication is due to be taken.

**Formalization of learning** described in ADR is a stage where all that is learnt solidifies into facts. Collected from various resources such as interviews and concepts during the literature review became a must include. Abstracting the learning into concepts for a class of problems, this step is identical to the DSR contribution types [17] as a level 2 nascent design theory where the contributing artifacts are concepts, constructs and design principles. All principles learnt at this stage didn’t make it to the application due to time constraints. These principles are reflected in the recommended changes of chapter 4. The principle of generalized outcomes states that principles and results at this point are generalized, there is a transition of specific and unique to generalized. The project doesn’t related well to this principle as the scope of the project was purposefully limited and generalized at the initial stages. Its important to note that this principle is project dependent while highly depending on the initial scope and cannot be applied to all DSR projects.

The Final hypothesis is where all of the learnt concepts come together. Final concepts are formulated based on cumulative knowledge of data gathered from interviews and empirical data both forming an informed argument while also contributing to the knowledge base.
3.3 Reflections

Taking up a problem that was highly specialized can be difficult, as the work carried out during the course of the project spans over several disciplines. The problem domain required to start this project needed to be highly specific. Understanding medical adherence while pointing out problems in the current system can be challenging. Available research on adherence is in abundance and highly specialized. Adherence to medication in lung related diseases is very different from the one that was found in kidney related problems for instance. The lowering of adherence was also found to be due to a plethora of reasons ranging from socio-economic problems to behavioral patterns. It required many iterations to understand the relevance from experts and empirical research.

As a researcher it is required to take into consideration plausible bias from interviewees and backing assumptions on empirical research done before hand. There is no set way to remove all bias from collected qualitative data specially from interviews. As a researcher is was important that open ended questions were asked to get a general idea of what was being said.

3.3.1 Evaluation

Evaluation of an artifact is key in DSR. A good evaluation method used to test the utility and efficiency of an artifact will eventually help integrate with the technical infrastructure of a business. Testing an artifact can be done in several ways from experimental to observational techniques. The prototype of the application acts as a proof of concept. Using informed argument the design of the application was motivated. From positive responses of the doctors and the increase of wearable computing devices in the market to be used in e-health forms a good argument. This form of technology needs to be adopted if not studied further to see potential gain. Functional black box testing was carried through out the project. Testing was done during development to check if the proposed modules were implemented
correctly. The design in prototypes for future iterations is not just conceptual but it is implementable.

### 3.4 Development Methodology

Developing in a team of one and try to work in agile is challenging. Having to perform several roles as the entire team can seem unnecessary and tasking. Using the principle from agile development, certain methods were adopted during the course of this project. Instead of jumping right into the Android Studio and start coding, it was important to first understand the domain subject. Making a list of all the topics on adherence and then prioritizing them was part of the first few steps displayed in the research design.

**Backlog** - This contained concepts that were broken down into small chunks. For example, studying only the factors that cause the lowering of adherence or the challenges faced to improve adherence. Ordering concepts that were understood after the initial literature review were moved up or down according to priority. This helped break down complex domain related topics into smaller bits.

**Sprint** - Using scrum practices very short spanned sprints were conducted lasting no longer than a week. During the sprint the key focus was to increase current knowledge base and improve on current understanding.

**Verify** - This stage most commonly took place after the data analysis phase. After collecting empirical data and qualitative data from the interviews the knowledge base was scrutinized to made sure that all facts learnt were facts in reality.

**Done** - This is when knowledge is added to the knowledge base and the next sprint was planned.

Though this form of methodology is designed for a team with members performing different roles, it helped me plan and structure the entire project in a systematic manner. The backlog can be found in the Appendix C.
Chapter 4

Implementation and Design

4.1 Introduction

In this chapter we go in-depth of the software side of the project, discussing the design guidelines used to program the phone and watch application. Following recommended guides from developer websites and established practices to code and the requirements that were put together before the application was programmed. We explore the software architecture of the smart watch and how it sits on top of the phone application, while briefly going through some connection framework used to send data between the phone and the watch.

We explain the rational behind the design and what motivated the modules in the application. The knowledge base motivated certain wireframes that were designed at the initial stages of the project. Following sections of this chapter include recommended changes for the next iterations of the application motivated by the knowledge base.
4.2 Software Architecture

The Android wear needs to be seen like an extension of the phone. Aiming to reduce the interaction with the phone and only showing what is important on the watch. Though the watch needs to be constantly paired with the phone future updates indicate that the Wear platform will be able to connect using WiFi and doesn’t require the user’s phone at all times.

![Figure 4.1: Wear to Application Architecture](image)

The Wear APK is part of the phone application which cannot run independent of the phone APK. It utilizes three different APIs to communicate with the phone. **Node API** - is essentially used to check if there local or connected nodes to the watch. Node events cater to all applications of the patent device.

**Message API** - is used to send messages between the nodes. They contain small private payloads communicating from application to application.

**Data API** - is used to transfer large data between applications. It connects all the devices within the Android Wear network.

Further information on these APIs can be found on the developer website referred in the bibliography [20].
4.3 Tools

The entire system was developed and designed with the help of various tools either to record, store or report data. Android Studio the official IDE by Google was used for the application development.

- **Balsamiq Mockups** - This is a wireframing tool, a quick and easy way to sketch out key UI/UX elements used in mobile and desktop applications. All the prototypes were developed using this tool. Balsamiq is a paid tool with a trial period for 30 days, it is important to note than the mockups were generated during the trial period of the application.

- **Simple mind** - A mind maps tool used to map out key features from the application as well as the theory.

- **Adobe Illustrator** - A tool by Adobe was used to illustrate and draw all the figures that were made in this document.

4.3.1 The Application

The application was built on Android studio with a minimum support for API 19 (Android 4.4 Kitkat). The source code was later adjusted to use some libraries from API 21 with the introduction of material design. Bluetooth Low Energy was introduced to Android from version 4.3 hence the justification to be backward compatible until version 4.4.

The Android version required to run the application is version 5.0 or Android Lollipop. This version of Android introduced a plethora of changes including a completely different UX. It is called Material Design, using clever ways to add a sense of layers to previously flat UI elements giving user a whole new way to indulge with the system.
During the literature review several devices were considered as wearable solutions, but due to the limitation on the devices available the Android watch was settled on. Devices such as the Fitbit allows users similar levels of access to its system features. Due to the limitation on the access of such devices the only platform
that was developed for was the Android Wear platform. Though other devices can be considered for such a project, the device needs to suffice certain requirements.

- The wearable solution needs to have an open platform that allows access to data retrieved by the wearable device and other miscellaneous sensors.
- The device should be easily worn by the patients without any discomfort.
- The device needs to be water resistant to allow multiple patients/users.
- The device needs to have long lasting batteries powering it for the entire day at the least. Currently the device needs to be charged every night to experience seamless assistance.
- The application/device needs to be fully automated and should not require any setup or interference.
- The device needs to support Bluetooth 4.0 LE technology for reduced power consumption.

**4.5 Design principals for adherence**

Designing a reminder tool can have most of the run-of-the-mill features such as time and a text input to notify the user what is being reminded of. Specifically designing the application for a niche purpose can be hard to differentiate. Allowing the user to add or remove certain tasks from the screen was going to be part of the design, but the way it was going to be presented needed to be studied.

As motivated by the research design the entire research process and design of the application was in iterations with a constant feedback loop changing and further motivating the design. During the initial prototypes the tasks and details to the tasks were in the same page with the assumption that it will take much lesser time for the user to enter their prescription. This feature changed in the following versions as Android guidelines specifies clear instructions of using a list view so that no other information is crowding the screen.
• **Principle 1** - Certain features didn’t make it to the development, features that were found to be crucial to the product from the literature review. Dr. Lars pointed it out that as the proposed system is a self reporting tool, there is a margin for error. Patients that aren’t motivated enough can falsify when they take their medicine. Hence, to better help curb their behavior on medication, it was suggested that patients be reminded 5 minutes right after they were supposed to have taken their medication. For example, the patient will initially be reminded at 2.00pm and then 2.05pm irrespective of the patient’s response earlier. This method of self reporting has been studied extensively in a paper from Jerent A [21] specially in patients with chronic illness.

• **Principle 2** - Pictures are very closely related to our sense of recall, attention, comprehension and intension [22]. Using informative pictures is nothing new in health care. Extensive research has been carried out to show the effects of pictures in the back of drugs and this application is not an exception. Having a glanceable UI allows an effective use of pictures. While the smart watch keeps track of all doses; missed or taken. The patient is notified when the dose is forgotten in the form of a graph instead of plain text allowing the patient to visually see when the dosage was dropped. This form of communication improves the patient’s behavior over time. Patients are said to highly benefit with the use of pictures specially when combined with written text [23].

### 4.5.1 Heuristics for a Smart Watch

Designing for a device that consists of a screen not more than 2 inches across can be challenging. Due to the limitation of screen real estate Google provided extensively detailed guidelines for designing and developing for a watch. These guidelines also include some heuristics that were followed during the design of the application.
1. **Focus on not stopping the user** - States that the watch is a perfect form factor that doesn’t interfere with the user’s day-to-day activities. It is possible to have the watch on while cooking, running etc. Hence the importance of timing when to show an application on the watch, when it requires user input is crucial to its design.

2. **Designing for big gestures** - States that given the small real estate of the screen the same gestures from the phone cannot be reused for a watch. Every element on the watch gets zoomed for the user to specifically navigate from screen to screen. The idea is to avoid the user from being swarmed with navigation menus and sub menus.

3. **Stream cards** - Talks about showing the right information at the right time and nothing else. As the entire Android Wear platform pairs with the phone, it should be easy to figure out when certain applications should be triggered making use of inbuilt sensors.

4. **Doing one thing, really fast** - This heuristic requires the application to be designed in such a way that it only requires a few seconds of attention from the user. Any longer duration for an application to keep the user engaged is not recommended specially considering power consumption.

5. **Reminder frequency** - Every time a user is being reminded that an application requires attention, the user is being disturbed. When a watch is strapped on a wrist throughout the day buzzing/vibrating the watch can cause annoyance. It is important to note that the watch shouldn’t be made to vibrate as frequent as the phone.

### 4.5.2 Prototypes

Given the guidelines from the section above and understanding the Android Wear framework, the following prototypes were designed using Balsamiq Mockups. They take deep consideration of all the heuristics discussed in the previous section and
some of them are evident in the prototypes. The figure below obeys the heuristics discussed in the sections above.

Figure 4.3a shows the general state of the watch when there are no notifications to be displayed. The precondition of this is that the watch is connected to its parent device via bluetooth.

Figure 4.3b is the first screen in the application when the user is notified that there is a notification. In this case it is an alarm notification that requires user input. The user can either dismiss or view the notification by swiping from left to right or right to left respectively. This view is designed by taking cues from the heuristic of designing for big gestures. In all screens the user only has at most 2 ways to interact with the application. The heuristic of *doing one thing, really fast* applies well in this case as the user will not be disturbed for too long and only required a single swipe to make a decision.

![Android Wear prototypes](image)

**Figure 4.3: Android Wear prototypes**

Figure 4.3c is invoked when the user chooses to view the notification. The user is presented a view of predetermined drugs that were inputted from the smartphone through the native application. To dismiss this page the user needs to swipe from left to right to go back to the initial screen(Figure 4.3a). This screen is highly glanceable and doesn’t require the users long spanning attention, obeying the first heuristic from section 4.5.1.


4.6 UML

4.6.1 Activity Diagram

The activity diagram below shows the work flow of the application pointing out the role of the watch and when it is triggered.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{activity_diagram.png}
\caption{Activity Diagram}
\end{figure}

Let's create a person named Bob. Bob usually takes care of his health but he has high blood pressure. As a result he takes Diuretics a popular drug for high blood pressure along with other medicines. He wakes up early in the morning to first put on his watch. He then opens the application in his phone to enter his new drugs he was prescribed from the doctor earlier that week. He registers the drugs and picks the exact time, date and how often he want to be reminded of the medication.

Later that day, after his lunch his watch beeps, reminding him to take his blood pressure pills. The reminder not only beeps on his watch but his phone as well.
With synchronized notifications, as he addresses and swipes the notification on the watch, the phone recognizes it as well. He then check the drugs making sure it was the blood pressure pills he needed to take. He is then reminded of it again 5 minutes after he should have taken the pills. He chooses to discard that notification and carry on with his day as he had already taken his pills. Such is the life of bob.

4.7 Screenshots

Continued on the following page to adjust page format...
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Figure 4.5: List view of all medications

Figure 4.6: Edit screen for the medications

Figure 4.7: Date picker

Figure 4.8: Deleting an entry
Chapter 5

Conclusion and the future

5.1 Answering the research questions

We started off with the question, if a smart watch is a tool that improves communication, specially to increase adherence. Various studies have been conducted with electronic reminder systems to improve adherence. In a study conducted by Hardy [24] compliance in adult patients had seen a drastic rise in a short span of 6 weeks with the help of a SMS based reminder system. Patients were required to send a response message 15 minutes after the initial message was sent. Principle 1 from chapter 4 addresses this issue with a repeated reminder. The smart watch falls under the sub genre of reminder systems which is assumed to be on the patient’s wrist at all times.

The second question is related to the ease of use and comfort level of the patient. The matter of comfort is subjective from person to person, reminder systems and SOS wristbands already exist and it is up to the patient to weigh the pros against the cons. During the interviews with Dr. Johan and Dr. Åsa both believed it was a necessary tool to help patients improve their quality of life. Further research and usability study need to be carried out to have comprehensible results. As mentioned in the following section, comprehensive experimental research needs to be carried out to assess the smartwatch over the smartphone.
The third question explores situations when the proposed technology cannot be of much help. Discussed in chapter 2 the challenges faced by electronic reminder systems in general to help improve compliance. Constraints that cannot be overcome via this technology are in situations where the patient has cognitive disabilities. Such disabilities are a broad classification of varying levels. In conditions where the patient has extremely low memory, low attention span, low visual or math comprehension the application itself can be hard to operate. Drawing a line of when it can and cannot be used is challenging, further research will be required to reveal the optimal condition. Patients with reading or linguistic difficulties can have difficulty reading or inputting their medication into the application. One way to overcome this difficulty can be to include functionality to adjust the size of text into the application.

5.2 Future development

The field of wearable computing is exciting and is full of possibilities. With the right permissions from patients and hospitals the prospects of wearable technology will have no bounds. A detailed literature review on other IoT devices might reveal devices that are more suitable for this particular use case.

- The aspect of entering one’s prescription into the phone application can be troublesome when there are more than a few drugs. With good use of image sensing algorithms the application should be able to read a prescription and automatically update the regimen.

- With the right permissions from the hospital and the patient, patient’s regimen should be able to be updated from the hospitals itself with a notification message to the patient’s phone. SMS based reminder systems have already seen positive effects boosting adherence up to 90% [25]. Adding push notifications to the devices will add an additional layer to boost adherence.
• A centralized database that keeps the patient’s profile synchronized with the hospital’s database would make it easier for doctors to communicate and diagnose giving them an overview of the patients’ performance. It would keep the phone and the watch synchronized with the hospital at all times.

• Users with mild cognitive disabilities cannot recall how their medication looks like packaging etc. In future versions a sound decision would be to incorporate a feature into the application that displays how each medicine looks like into the watch itself.

• Experimental research needs to be conducted if reminder systems on a smart-watch are in fact better than reminder systems on a phone.

5.2.1 Adaptability

The proposed version of the application, one different from the artifact will have to adapt to all types of regimens. Irrespective of the hospital or the type of medication prescribed the application needs to cater to the patients. In future work, the adaptability of the application will purely depend on the data source. There lacks a common type of data source that can power the application with various appointments and prescription data. In Sweden, funded by the government an organization titled Health Innovation Platform which allows developers to use open data APIs to develop within e-health. Tools and APIs like these can allow developers to shape how the application might function one day, making it highly versatile.

5.3 Design contributions to research and practice

We sum up by shedding light on some of the contributions made during the duration of this project. Starting with understanding the problem and understanding
the intricate structure of the health care system with the patients and the role a
doctor plays, help us understand that there is much scope for improvement. The
thesis proposes design guidelines to consider when designing for a smart watch.
The knowledge base gives concrete results in showing that certain guidelines will
help us improve adherence. The principals mentioned in section 4.5 help us to un-
derstand that aiming to improve adherence is not an easy task. Those principals
can not only be applied to smartwatches but to any wearable device. After re-
searching various studies that were previously conducted with electronic reminder
systems and clearly seeing their potential, the smartwatch can be a valuable tool
to help improve adherence. A well executed application that obeys the guidelines
from the previous chapters will prove to be highly valuable.

5.4 Conclusion

In an ideal setting with time as no constraint, after conducting a usability study
the application would have to be tested in a real-world setting where patients
wearing the watch on a daily basis will be monitored. This would be the initial
step to test the application over a period of time to know if it influences adherence.
Testing and evaluating it in an observational study as stated in design evaluation
methods as a case and field study.

Taking from the literature review, trust between the doctor and patient is key
to any treatment. Building on trust levels can highly benefit adherence and the
patient’s wellbeing as a whole. The road to treatment is a hard one and a shared
decision made by the patient and the doctors will benefit the entire system greatly.

A highly beneficial way to improve adherence is greater layers of interventions.
Care sent to the patient’s home as reminders or short messages via SMS can go
a long way. What might seem to be an investment at the beginning will end
up saving the heathcare system millions. Non-compliance remains to be a huge
problem to the health care industry today, with clever and innovative technology
this problem can soon be overcome.
Appendix A

Studies on reminder systems
Table A.1: Previous studies made on reminder systems and their response on adherence

<table>
<thead>
<tr>
<th>Author, study design</th>
<th>Study population</th>
<th>Type of reminder</th>
<th>Intervention</th>
<th>Frequency of measurement</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardy et al, RCT parallel</td>
<td>Adult patients with HIV</td>
<td>SMS (vs beeper)</td>
<td>Everyday personalized message for each dose. Response with text message required. If no response given the phone would beep every 15 min</td>
<td>Baseline, week 3 and week 6</td>
<td>High amount of difference in adherence were found favoring SMS, when measured with electronic monitoring</td>
</tr>
<tr>
<td>Pop-Eleches et al, RCT parallel</td>
<td>Adult patients with HIV</td>
<td>SMS</td>
<td>Interventions based on regular reminders via SMS</td>
<td>Baseline set for 12-week periods in 48 weeks</td>
<td>Reminders sent at the end of every week saw 90% adherence increasing by 13–16%.</td>
</tr>
<tr>
<td>Hou et al, RCT parallel</td>
<td>Women on oral contraceptives</td>
<td>SMS</td>
<td>Interventions based on regular reminders via SMS</td>
<td>3 month periods</td>
<td>No difference in adherence was found.</td>
</tr>
</tbody>
</table>
Appendix B

Interview questions

1. Do you think adherence changes depending on the type of disease?

2. Do you think your patients will prefer wearing a smart watch on their hand everyday?

3. Do you think your patients will remember to charge it every other day? Based on the fact that they are convinced the smart watch works

4. How often do you ask your patients if they have been taking their medication regularly?

5. How does the system act when the patient is psychologically unstable?

6. How do social factors affect the patient and their ability to buy medication?

7. How well versed are you with the cost of medications in your area of specialization?

8. Does the exact time matter when taking the medication or is it between certain times?

9. What is the first line of thinking when the patient is still in grief after prescribing effective medications?

10. How long do you wait before changing/dropping the medication?

11. How do you know if your patients are taking their pills?

12. Would you prefer your patients be reminded of their medication via SMS?

13. What is your line of thought when the patient purposefully does not take the medication?
Appendix C

Backlog
Figure C.1: Midway snapshot of the backlog
Bibliography


