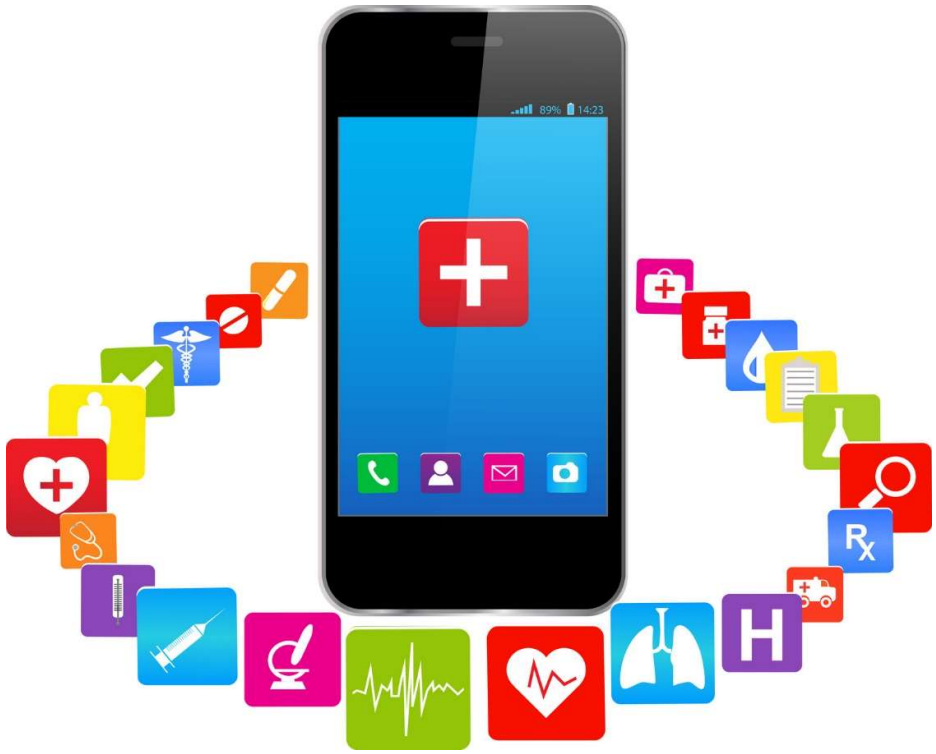

Medical App Adoption in the Dutch healthcare sector

A study on self-management apps for chronic conditions

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Abstract

Today's Appstores include thousands of medical apps available for self-care purposes in the treatment of chronic diseases like Diabetes and COPD. Among the many available apps, very few are seamlessly integrated in the healthcare ecosystem. A lot of reporting functionality is still left to manual work, and healthcare professionals cannot connect the app with their professional information systems. This thesis investigates the adoption barriers to medical apps in the Dutch healthcare market from a multi-stakeholder perspective. The aim of this research is to identify possible solutions for medical app developing organizations to increase the chance for adoption of an app.

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Glossary

HCP	Healthcare professional
mHealth	Mobile health; often used interchangeably with eHealth
eHealth	Electronic health; often used interchangeably with mHealth
EPD	Electronic Patient Database, or medical record
ECG	Electrocardiography: a recording of heart's electrical impulses, a person's heartrate over time
COPD	Chronic Obstructive Pulmonary Disease (lung disease)

1 Introduction

The focus of this research is on an emerging industry, which combines the domain of mobile technologies with healthcare: mobile healthcare (mHealth). This combination resulted in an explosion of research and solutions focused on supporting HealthCare Professionals (HCPs) and patients in the treatment of a disease through the use of mobile devices (i.e. smartphones and tablets) and their associated applications (apps) (Ozaydin, Zengul, Oner, & Delen, 2017). The market for these mHealth apps, or 'medical apps', has rapidly evolved, as patients are increasingly interested in using apps for (self-)care purposes (Baum & Abadie, 2013; Gallagher, O'Donoghue, & Car, 2015; Xu & Liu, 2015). Similarly, there is a strong and increasing interest in medical apps among HCPs, health insurers and national governments (Boulos, Brewer, Karimkhani, Buller, & Dellavalle, 2014; Coöperatie Zelfzorg Ondersteund, 2014; El-Gayar, Timsina, Nawar, & Eid, 2013; Gagnon, Ngangue, Payne-Gagnon, & Desmartis, 2015; Ministerie van VWS, 2014; Nictiz & NIVEL, 2014). A study of the VvAA (2013) shows that 72% of participating HCPs (n=1,617) are interested in the application of mHealth.

With the introduction of medical apps, healthcare could be applied more effectively and bring significant reductions in healthcare expenditure (Dehzad, Hilhorst, Bie, & Claassen, 2014; Rossi et al., 2010). Moreover, eHealth has been proven to reduce national health disparities and improve health equity (Khoja & Durrani, 2017). Apps for self-care purposes enable patients to keep in touch with their HCP independent of location and time. Since patients exchange information over the internet and data is directly accessible to HCPs, less consults are necessary and the time per consult decreases (Kaufman, 2014; Tonarelli, 2015). To illustrate: "In a US budget impact model for diabetes, self-management technology delayed complications and generated savings to the health system. Remote monitoring of blood glucose, alone, saved $326 million over ten years" (Tonarelli, 2015). However, as only few case studies are available, more research is needed to increase awareness in the market and prove the efficacy of mHealth apps (Gallagher et al., 2015; Kaufman, 2014).

In The Netherlands, back in 2014 the minister of health called out to the House of Representatives in order to draw attention and emphasize the importance of mHealth (apps) in the near future. To stimulate the adoption, the Ministry of Health, in consultation with parties in the Dutch healthcare sector, announced three key ambitions to increase the quality of life through mHealth by 2020 (Ministerie van VWS, 2014):

1. 80% of all chronically ill patients and 40% of the remaining population should have direct access to medical information and test results via mobile apps and/or online web portals.
2. 75% of all chronically ill and elderly should have the option to perform measurements independently from a HCP, often in combination with remote monitoring by HCPs.
3. Everyone receiving care at home should be able to communicate via internet with their HCPs 24 hours a day and seven days a week.

Although the expectations of mHealth are high, adoption and innovation are hindered by many obstacles. Such obstacles include (but are not limited to) privacy issues, preference for face-to-face interaction, lack of technical knowledge of medical staff, resistance to change and costs (Abelson et al., 2017; Scott Kruse et al., 2018). To overcome these challenges and stimulate nation-wide adoption, more research is required on methods or artefacts which allows its users to take such challenges into consideration, bring together necessary stakeholders to work past these challenges and create guidelines or best practices for future mHealth development (Dehzad et al., 2014; Khoja & Durrani, 2017).

1.1 Problem Statement

Several factors hinder the adoption of mHealth. The rapid development of mHealth in the recent years has resulted in a plethora of medical apps from which users can choose. With this increased number of medical apps, more challenges have surfaced (Dehzad et al., 2014; Gallagher et al., 2015; Khoja & Durrani, 2017; RIVM & Nictiz, 2013). Questions arise, such as:

- How does one know that the information provided by the app is correct and safe to use?
- Are patient data secure and how does an app indicate conformity with international privacy standards such as GDPR?
- Who is responsible for erroneous information provided by the app?
- Who is responsible for inappropriate user actions based on app output?

The potential risks along with the vast availability of apps creates demand for regulation. New (supervisory) institutions are being established such as Zelfzorg Ondersteund (a coalition of HCPs, patient federations and health insurers) or Assuring Medical Apps by Deloitte to develop standards, monitor and approve medical apps in terms of usability, functionality and safety (Coöperatie Zelfzorg Ondersteund, 2014; Jacobs, 2015; RIVM & Nictiz, 2013).

However, fulfilling the basic criteria does not automatically imply that an app is accepted by HCPs, patients and/or health insurers (i.e. the healthcare ecosystem). More and more apps will comply to newly developed regulations and policies, but how will relevant stakeholders make a selection from all the potential apps? At this time large-scale implementation lags behind and more research into the adoption of mHealth is required (Coöperatie Zelfzorg Ondersteund, 2014; Dehzad et al., 2014; Ministerie van VWS, 2014; Schippers & van Rijn, 2014; Wu, Li, & Fu, 2011).

A recent study of Nictiz & NIVEL (2014) about the Netherlands indicates that, according to the IMS Institute for Healthcare Informatics, the main challenge for patients is to find the one app that best suits their needs among the thousands available. HCPs are faced the same challenge when they try out apps, prior to making recommendations to patients. A similar survey in the UK by PatientView (2013) concludes equal outcomes (Banner, Nead, Wyke, Case, & Newbold, 2013). In the Netherlands, 64% (n=161) of the HCPs say they have recommended apps to their patients and according to the VvAA (2013) one out of six HCPs (n=1,182) has even prescribed one or more apps to a patient (Nictiz & NIVEL, 2014; VvAA, 2013).

These studies show the demand and potential of mHealth, however different stakeholders still perceive a lack of guidance when it comes to selecting a certain app for a specific need. Regulation is still in an early stage and by today there are no specific selection guidelines. Hence, even though there are many mHealth apps available for many different situations, adoption occurs on an individual rather than a nation-wide level. Moreover, even when adoption occurs, it is unknown how different stakeholders go through the process of selecting a suitable app solution and what selection criteria are considered.

1.1.1 Research Questions

Following the problem statement, this thesis aims to identify mHealth adoption barriers and corresponding solutions all relevant stakeholders by posing the following Main Research Question (MRQ):

MRQ: How can the adoption of medical apps for patients with chronic conditions in the Dutch healthcare sector be improved?

The implied goals of our MRQ are to investigate the interests of healthcare professionals, patients and health insurers in medical apps, how they make their choice for using a specific app and how they can be supported in the app adoption process. By understanding the preferences of the stakeholders, we aim to find those factors that determine whether an app can be successfully adopted or not. These factors are input for an instrument to be constructed which may serve as a coherent set of guidelines (possible solutions) to improve the adoption of a medical app. As the criteria and interests of multiple stakeholders are taken into account, the instrument will consist of a comprehensive overview to offer breakthrough opportunities for existing barriers and provide medical app developing organizations powerful tool to maximize the potential for adoption. To realize these goals, we divided the MRQ in six sub-questions:

SQ1: What factors are important for successful adoption of medical apps in the market according to literature?

By performing a literature study on medical apps and the barriers to adoption of these apps, this sub question will result in an overview of factors that potentially can improve the adoption of medical apps in the market. The different barriers from literature will be classified and are input for discussion in the expert interview sessions.

SQ2: Who are the stakeholders involved in the Dutch healthcare sector?

The answer to this sub question will provide insights on the different parties involved with medical app adoption in The Netherlands and how they relate to each other. This results in an overview that explains the structure of the Dutch healthcare market.

SQ3: What factors are important for successful adoption of medical apps that healthcare stakeholders consider?

By conducting expert interviews the answer to this sub question will provide an overview of both, the barriers to adoption, and solutions to overcome these challenges from a multi stakeholder perspective. What each stakeholders' interest are, what challenges they face and the conditions which they believe are crucial for the adoption of a medical app in the healthcare market are points for discussion.

SQ4: How do the factors for successful medical app adoption from both literature and the different experts relate to each other?

This sub question will provide a final classification of the factors that are important for solving the challenges in the adoption of medical apps. It provides insight into the different stakeholder interests in which they are asked to prioritize the factors to what they think is key for increasing adoption in the healthcare market.

SQ5: How to construct an instrument that supports medical app developing organizations in such a way that more apps find adoption in the market?

This sub question comprises the identification of the key elements for the construction of the instrument to guide medical app developing organizations in the adoption process, with the result that existing barriers to adoption can be overcome.

SQ6: What is an appropriate way to validate the proposed instrument?

With this sub question the validation method for the instrument is defined.

1.2 Scope

Given the vast smartphone application market there are various types of medical apps available in the app stores and all labeled as 'medical app' or 'health app'. Therefore, it is important to determine the scope of this study. In this research the focus is on patient apps for self-care purposes, in particular apps that aid patients in managing chronic disease. Additionally, we only focus on stakeholders present within the Netherlands, and therefore consider any country-specific (except the Netherlands) data as out of scope.

This specific focus is chosen because the availability of apps for patients largely consists of self-care apps for chronic diseases such as diabetes and COPD (Boulos et al., 2014). Furthermore, as mentioned in the introduction, the Dutch Ministry of Health targets the chronically ill by demanding that by 2020 at least 80% of all chronically ill have direct access to medical information through apps and 75% should have the option to perform measurements independently in combination with remote monitoring (Schippers & van Rijn, 2014).

1.2.1 Definitions

Before we can successfully answer our research questions and apply our scope, we need to properly demarcate the meaning of medical apps. As such, we define medical apps as: "*mobile applications for smartphones and tablets used for monitoring health status and improving health outcomes of patients*".

In literature, there are a plethora of different definitions for mHealth apps. For example, Istepanian et al. (2005) define mHealth as "mobile computing, medical sensor, and communications technologies for health-care" whereas the definition of the United Nations and the Vodafone Foundation includes specific communication technologies: "mHealth involves using wireless technologies such as Bluetooth, GSM/ GPRS/3G, WiFi, WiMAX, and so on to transmit and enable various eHealth data contents and services. Usually these are accessed by the health worker through devices such as mobile phones, smart phones, PDAs, laptops and tablet PCs.". As can be seen in our definition, we focus solely on applications for smartphones and tablets, and therefore disregard standalone medical sensors.

The World Health Organization defines mobile health as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices and personal digital assistants (PDAs)".

Kumar et al. define mobile health as the application of mobile technology either by consumers or providers, for monitoring health status or improving health outcomes.

In this paper *medical apps* is defined as mobile applications for smartphones and tablets used for monitoring health status and improving health outcomes of patients.

1.3 Relevance

1.3.1 Scientific Contribution

The scientific contribution of this thesis is threefold:

1. First, we investigate different barriers that hinder the adoption of mHealth by interviewing experts and thereby add to the current knowledgebase of barriers of mHealth. As such, we adhere to the request of Gallagher et al. (2015) and Kaufman (2014) of specifically researching mHealth adoption barriers.

2. Additionally, for each identified barrier, we ask the experts for potential solutions. Although adoption barriers of mHealth apps have been researched in manifold, to the knowledge of the researchers the emphasis was never of possible solutions.
3. Lastly, this thesis provides several opportunities for future research. The identified solutions to the barriers can be further researched in greater detail in order to improve the adoption process even further. Moreover, the created framework can be used in future research as to increase its validity.

1.3.2 Societal Contribution

The societal contribution of this thesis is threefold:

1. First, the created framework can be used by entrepreneurs and developers to make increase the quality and adoption rate of mHealth apps.
2. Furthermore, following the increased quality and adoption of mHealth apps, the patients' lives will improve due to the value added by the mHealth apps.
3. Lastly, as patients will use more mHealth apps, the face to face time with HCPs will decrease. The saved time for HCPs can subsequently be used to increase the caregiving to other patients/manners.

To conclude, we understand that a lot of topics and research questions regarding mHealth need more coverage in order to realize its full potential, but unfortunately due to limited time and resources, this thesis will only focus on adoption barriers in the Dutch healthcare ecosystem. Nevertheless, we hope that this thesis will provide solid research materials to enable researchers and professionals develop better methods and apps, eventually leading to an increase in the adoption rate of medical apps.

1.4 Thesis Overview

The subsequent chapters detail the research approach of this thesis. Next, we discuss general related literature and adoption specific articles in Chapter 3. Chapter 4 presents the results from our expert interviews followed by Chapter 5 in which these results are related to literature and a structured overview of adoption guidelines is created to help medical app developing organizations. Finally, we present our conclusions and threats to validity in Chapter 6.

2 Research approach

We present the four research methods that were utilized in this research: a literature study, multiple expert interviews, documentation study and design science. The research model in Figure 1 is adapted from the research method by Verschuren and Doorewaard (2007) and depicts the main research objectives for this research. The research is divided into three steps, from left to right:

A. Literature study;
B. Validation interviews and expert interviewing;
C. Design science: creation of an artefact that guides stakeholders in the adoption of medical apps

The numbers one to four each represent one of the research techniques that have been used in the execution of this study. Dashed boxes delineate the processes which have been carried out and solid boxes depict the deliverables of these processes.

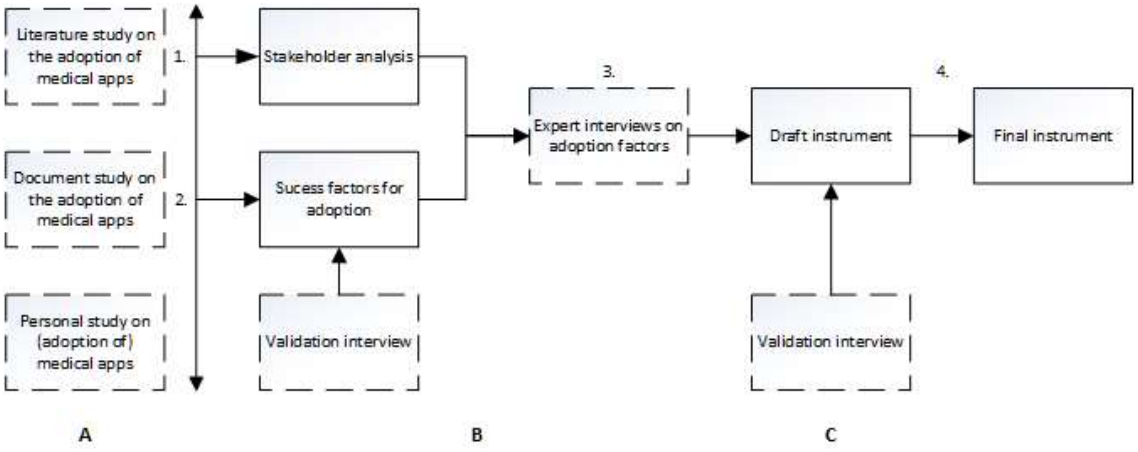

Figure 1: Research model

2.1 Literature Study

A firm understanding of contemporary mHealth apps and relevant literature is necessary to properly formulate our research questions and design appropriate case study protocols and expert interview questions. As such, our research starts with a literature study in Chapter 3. Although our initial plan included performing a structured literature review (SLR), a quick Google Scholar query revealed many existing SLRs in the area of mHealth (apps) already such as (but not limited to) Gurman, Rubin & Roess (2012), Sezgin and Özkan (2014), Plaza et al. (2013), Zapata et al. (2015) and Naslund et al. (2015). Given our time constraints, we will use these existing SLRs and subsequently search through literature using the snowballing technique.

Using the snowball method (Biernacki & Waldorf, 1981) the maximum number of papers we include through snowballing is 3 levels deep from the initial paper. This results in the following inclusion: in the initial paper we find a reference to paper A (first level, included), in paper A we find a reference to paper B (level two, included) and in paper B we find a reference to paper C (third level, included). If we discover new papers through references in paper C these results will be excluded as the termination criterion for snowballing is set to a maximum of three levels deep.

Lastly, we extend our literature study by querying the MEDLINE, EMBASE and Google Scholar databases to include articles specifically focused on factors which influence mHealth adoption in order

to answer SQ1: '*What factors are important for successful adoption of medical apps in the market according to literature'?*

2.2 Document Study

As mentioned in our scope (Section 1.2), we solely focus on mHealth adoption within the Netherlands. As such, we are only interested in adoption guidelines (specifically) designed for the Dutch healthcare market. To familiarize ourselves with the Dutch (mobile) healthcare ecosystem and to answer SQ2: '*Who are the stakeholders involved in the Dutch healthcare sector?'*, we studied several documents from governmental bodies as well as several other Dutch organizations such as the Ministry of Health, Zelfzorg Ondersteund (a coalition of HCPs, insurers and patient federations), the RIVM (a research institute in healthcare by the Dutch government), Nictiz and Nivel (healthcare research) that provide a yearly eHealth monitor with research statistics on the Dutch healthcare market, a publication by Deloitte on Cyber security research on connected medical devices, a publication by the VvAA on mobile health offering (Coöperatie Zelfzorg Ondersteund, 2014; Ministerie van VWS, 2014; Nictiz & Nivel, 2016; RIVM & Nictiz, 2013; Slobbe, 2015; VvAA, 2013).

2.3 Expert Interviews

After investigating available relevant literature and documents, we categorize and present our finding to 13 experts (Table 1). During these 40 to 60-minute interviews, we ask the experts to prioritize different barriers, complement missing barriers and suggest potential solutions in a semi-structured manner to answer SQ3: '*What are the success factors for adoption that healthcare stakeholders consider?'*. More specifically, we ask each expert for the most important five adoption barriers, and subsequently let them divide 100 points over these barriers to develop a sense of importance. Due to the semi-structured nature, we can dive deeper into specific barriers when necessary. The full interview protocol can be found in Appendix 8.2. The individual interview notes and recordings can be made available upon request.

Table 1: Overview of the experts consulted in this thesis

ID	Role	Organization	Expertise
1	Product manager	Patient Federation	eHealth
2	CEO	Cooperation of patient groups representatives of primary care providers and almost all Dutch insurance companies	mHealth, chronically ill
3	Senior policy officer	Branch organization of healthcare organizations in nursing and homecare	Healthcare innovation, Information policy
4	Physician	Medium-sized hospital	Emergency physician, eHealth/mHealth/Apps
5	Diabetes consultant	Medium-sized hospital	Medical devices
6	General practitioner	GPs practice	eHealth/mHealth
7	Consultant	Independent E-health advisor	eHealth strategy, policy and product development
8	Policy advisor, medical advisor	Association of insurers	Health policy
9	Senior advisor	Leading (big4) health insurance company	Care strategy
10	COO	Dutch market leader healthcare innovation and deployment of (home)care technologies	Development of Home healthcare innovations
11	Senior policy advisor	Dutch Ministry of Health	Mobile health, healthcare innovation
12	Senior advisor	Center of expertise for eHealth	Health and ICT, eHealth
13	Physician; CMO	Medium-sized hospital; Dutch market leader in medical app development	Urology, mHealth

As can be derived from Table 1, experts have different backgrounds and represent five different types or organizations: health insurers, healthcare professionals, patient federations, governmental institutions and medical app developing parties. We specifically chose to interview experts from various background to gather different (opposing) perspectives on adoption barriers. The experts were contacted in person or by email and were found by querying search engines and using our personal network. Questions which arose after the interviews were resolved through email. After each interview, we coded the answers, which can be made available upon request.

After coding all the interviews, we compare the adoption barriers and suggested solutions from the expert interviews with the ones found in literature to answer SQ4: '*How do the success factors from both literature and the different stakeholders relate to each other?*'. Based on our finding we can create and/or improve guidelines which aim to improve medical app adoption.

2.3.1 Validation Interview

We present our guidelines to an additional expert during a guidelines validation interview to answer SQ6: '*What is an appropriate way to validate the proposed instrument?'.* Within this interview the expert is given the opportunity to evaluate our adoption guidelines and present feedback. Using this feedback, we will adopt our guidelines in a second (final) iteration. Although we would have preferred to validate our guidelines by multiple experts, this was not possible due to time constraints. The interview protocol for the validation interview can be found in Appendix 8.3.

2.4 Design Science

We aim to create an artefact that helps medical app developing organizations to maximize the potential for adoption of an app. Our ambition to help society is consistent with the goals of design science: "Whereas natural science tries to understand reality, design science attempts to create things that serve human purposes" (March & Smith, 1995). The design science paradigm consists of two iterative processes, namely create and evaluate. We approach these processes according to IS framework from Hevner et al. (2004). This framework has been thoroughly tested as a vehicle for "understanding, executing and evaluating IS research combining behavioral-science and design-science paradigms".

Figure 2 applies the framework to our research. We conduct our research in an Environment consisting of Healthcare Professionals (physicians, nurses, GPs, etc.) whom recommend and collaborate with patients through medical apps (a combination of mobile and medical technologies). These medical apps are developed by medical app producing organizations (more specifically by medical app developers). Furthermore, health insurers, patient federations, organization federations, hospitals and regulatory bodies influence the adoption of mHealth app based on their preferences. The foundation of our knowledgebase consists of existing theories found in the domains of medical apps. We extend our knowledge provided by the foundations by applying the methodologies of design science, expert interviews and literature study to develop app adoption guidelines to answer SQ5: '*How to construct a framework that supports healthcare stakeholders in such a way that more apps find adoption in the market?*'. Upon completion, a single expert evaluates the guidelines through an expert interview and provides input for future iterations to answer SQ6: 'wh*at is an appropriate way to validate the proposed instrument*?'.

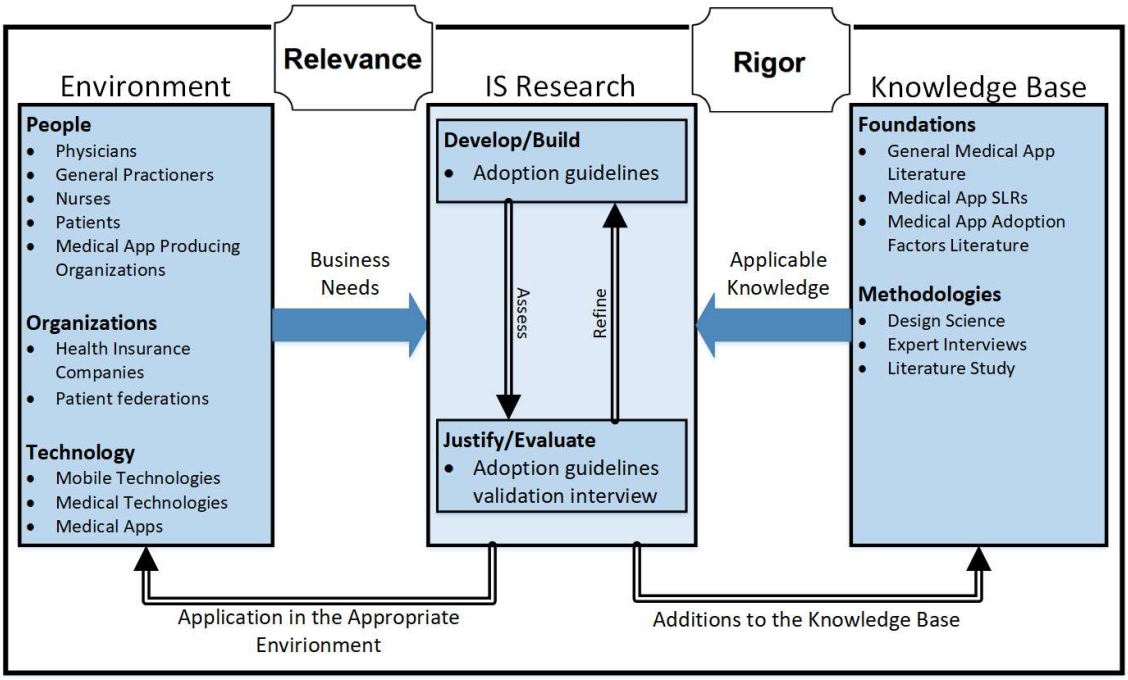

Figure 2: the IS research framework adopted from (Hevner et al., 2004)

3 Theoretical background

3.1 Classification of medical apps

By researching existing classifications of medical apps in scientific literature, this chapter will provide an overview of the different types of medical apps that exist in the mobile app market places: Google Play and the Apple App store.

The definition we use for medical apps as mentioned in Chapter 1.2.1 is: “mobile applications for smartphones and tablets used for monitoring health status and improving health outcomes of patients”.

Since there are many different types of medical apps mentioned in existing literature, the classifications will explain the focus for investigation in this paper.

3.1.1 History of medical apps

Mobile phone applications, or apps as we know them today have become part of our daily life. The technological innovations in the past five years resulted in a tremendous increase of apps for any kind of use, including facilitating patients in the treatment of chronical diseases. The online app stores are an example of such an innovation, being a place where app developing companies can offer and sell their applications to end-users. The website www.statista.com and www.sensortower.com show that in 2017 the two largest app stores (screenshot in Figure 3) are the Google Play store with over 2.6 million apps and a $20.1 billion US dollar of consumer spending, and the Apple App Store with over 2.2 million apps available and a consumer spending of $38.5 billion US dollars. In comparison, in 2015 the Apple App store was good for 1,5 million apps, if we go back a few more years, in 2010 the counter shows only 150k apps. Interesting to see is that when we look at apps labeled being ‘mHealth apps’ the number in the Apple App store has been increasing up to and including quarter 3, 2016. Since then the numbers show a constant pattern fluctuating between 46k and 48k apps.

Other websites however, such as www.research2guidance.com provide different statistics on mHealth apps: 158k for the Google Play store and 150k for the Apple app store in 2017 (screenshot in Figure 4). A reason for the difference is that different parties use different classifications for mHealth apps. Where some only include the medical apps others also include fitness, nutrition and lifestyle related apps.

Figure 3: Number of apps available in leading app stores (Statista, 2017)

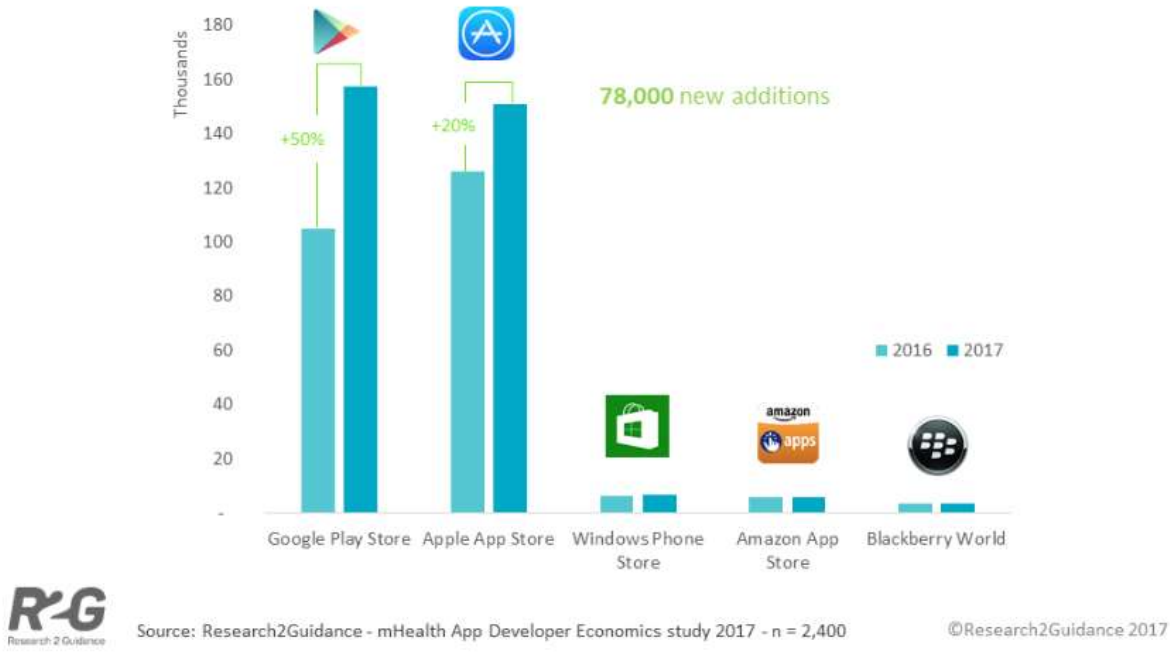

Figure 4: Number of mHealth apps available in leading app stores (Research2Guidance, 2017)

3.1.2 Classification by Free and colleagues

As can be seen from the statistics and suggested in the literature by Boulos et al. (2014) and Dehling et al. (2015), a categorization is required as the purpose of mHealth apps can differ and not all are considered to be medical apps. In this thesis, we adhere to the classification by Free et al. (2010). In their paper, they present a classification of mobile health applications (Figure 5) divided in three main categories:

- Tools for health research
- Improving health services
- Improving health outcomes

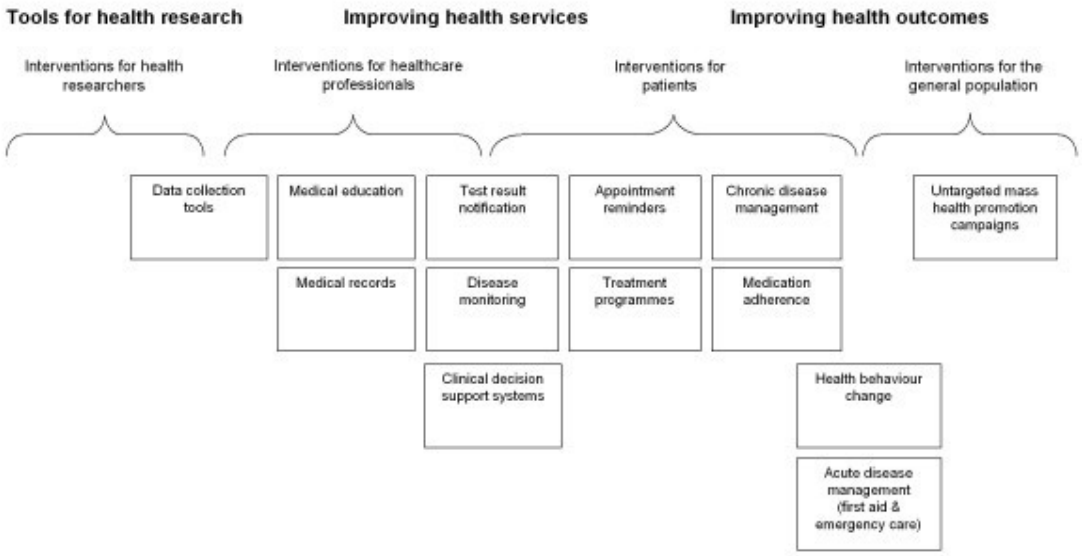

Figure 5: mHealth app classification (Free et al., 2010)

We selected this classification because it matches with our definition and scope as described in Chapter 1.2. Within the below classification we focus on the apps that target interventions for patients, specifically the apps with the functionality of chronic disease management, treatment programs and disease monitoring.

3.1.2.1 Chronic disease management

As explained in our scope in Chapter 1.2, we focus on self-management apps that target chronic diseases. These apps support patients in different ways to stay in control of their disease. For example, diabetes patients can use an app to count the amount of carbs in a meal and the corresponding insulin dosage they should take. Furthermore, they can register glucose measurements in a diary which can be useful for analyzing patterns and reporting to their health care professional.

3.1.2.2 Treatment programs

Apps that offer treatment programs allow the patient to be in control of their disease by managing (part) of the treatment process from home using self-care technologies. An app can increase convenience and help patients improve their health outcomes through a combination of self-care and HCP guidance. Instead of visiting or staying in the hospital, the app is the medium for communication between the patient and the HCP to keep track of the treatment progress.

3.1.2.3 Disease monitoring

Disease monitoring allows patients to live their daily life at home without direct supervision of a HCP. (Automatic) measuring such as heart rate, blood pressure and glucose levels can be done through smart devices at home while the data is transmitted (sometimes in real-time) to an online server that is in connection with the HCP. In case of an incident, the system will directly report this to the HCP or if urgent call for an emergency.

3.2 Medical app adoption: barriers and solutions from literature

In this chapter we will share the results of the literature study on the selected medical app categories as described in the previous chapter. A summary of the addressed papers can be found in Appendix 1.1. Of all the barriers to adoption that were found in the literature, we started with writing down each individual barrier and if available the corresponding possible solution(s) to overcome the barrier. From a total list of 44 barriers we have grouped same or similar results together resulting in a set of six different categories and a total of 23 unique barriers that are summarized in Table 2. In the following subchapters we will explain the barrier categories and for each category we provide a summary of the literature findings.

Table 2: Medical app adoption barriers from literature

	Perceived usefulness and ease of use
1	Functional deficiencies: lack of individually important functions; unnecessary functions; lack of customization
2	Complexity of app use, handling too complicated
3	Small screen size, battery consumption, need to carry smartphone all time
4	Time consuming (disruptive to workflow)
5	Lack of decision support (to manage own condition)
6	Lack of continuous monitoring
	Dependability and evidence
7	Accuracy, reliability and validity of sensors and systems
8	Assurance: compliance, control, verification of data (appropriate content)
9	(Lack of) quality standards: app functioning should have an assured quality
10	Availability of the content
11	Lack of clinical approval of the app
	Security, privacy and regulations
12	Privacy (protection of personal private data, vulnerability to loss smartphone)
13	Lack of governance, app regulations
14	Medicolegal issues: Implications if HCP failed to act on readings that had been transmitted. Professional security, clinical uncertainty.
	Integration and interoperability
15	Compatibility with the work process, HCPs can have different ways of working
16	Lack of interoperability with other devices, apps, web portals
17	Integration with current healthcare systems
	Individual and experience
18	Motivational and emotional barriers (lack of additional benefits, no joy of using app or smartphone, loyalty to keep using mobile app for therapy, stigma/blame/fatigue because being confronted with disease all day)
19	Digital and health literacy levels: difficulties in using smartphone, unawareness of existence medical app for disease management, lack of professional experience, difference between younger/older/disabled people.
20	Accessibility to a mobile device (young children, elderly)
21	Visual, auditory and cognitive disabilities
	Financial
22	Apps must be cost-effective in their use
23	Implementation costs / available budget, increased cost of care. No cost compensation or reimbursement for implementation. Cost benefit ratio unacceptable (cost of smartphone, data plans, fee for using app).

3.2.1 Perceived usefulness and ease of use

This category contains barriers that are directly related to app functionality. In the literature, many studies mention that there are still many cumbersome apps being developed that lack a user centered design approach such as (but not limited to) Abelson et al. (2017), Boulos et al. (2014), Demidowich, Lu, Tamler, and Bloomgarden (2012), Gagnon, Ngangue, Payne-Gagnon and Desmartis (2015), Katz, Dalton, and Price (2015) and Kaufman (2014). The study of Scheibe et al. (2015) investigated the factors that influence the acceptance of diabetes apps among patients through interviews with elderly patients followed by the testing of two diabetes apps. The authors explain that the end-users in their experiment often experience difficulties in using an app solution and that handling app functionality is too time consuming. Results from their study reveals that patients often feel that apps lack individually important functions or that functionality that the app offered were unnecessary for their own treatment needs. Action to overcome these issues are among others: a user centered design approach (i.e., involve the end-user in the development process and focus on their needs) and the ability to allow users to customize app functions referred to as individual tailoring (El-Gayar et al., 2013; Nictiz & Nivel, 2016; Wu et al., 2011). Another often-mentioned solution is the automation of health data entry. Patients are not interested in long and boring tasks of copying data manually between devices. Taking this burden away by for example using a Bluetooth connection between the measurement device and the app will drastically increase the ease of use for patients (El-Gayar et al., 2013; Katz et al., 2015; Kaufman, 2014).

The third barrier item in the list is related to the mobile device specification: factors on why using a smartphone is unpleasant in use such as small screen size, battery consumption and having to carry it with you all time (Casey et al., 2014). However, the papers that state these barriers all refer to findings from before 2015 and it is expected that most of these obstacles are no longer an issue today given the technological improvements over the past years.

The last two barriers in this section are the lack of decision support through apps and the lack of continuous monitoring. Automated analysis and rule-based interpretation of data tailored towards the individual patient, like (real-time) insulin dosage calculation based on carb intake for diabetes patients would be helpful in the treatment process and stimulates healthy behavior (El-Gayar et al., 2013).

3.2.2 Dependability and evidence

The second barrier category is about quality requirements of medical apps and the extent to which HCPs can depend on medical device sensors and systems' data. When it comes to more critical figures HCPs often find it hard to rely on new technology that hasn't proven itself yet and furthermore questions arise whether the offered content through apps is safe and appropriate for patient use (Beatty, Fukuoka, & Whooley, 2013; Gagnon et al., 2015; Kumar et al., 2013). As medical apps use is still in an early stage and regulation on quality standards lag behind, it is difficult for HCPs to be open to new app initiatives. Before HCPs feel for including apps in their treatment approach they want to be hundred percent sure that the solution is clinically safe to use. Banchs et al. (2014) states that a strategy to demonstrate clinical benefits with the use of innovative technology is urgently needed. Actions that can be taken to overcome these barriers are the use of quality standards, when an app complies to certain standards, HCPs can start with trials that can generate evidence on proper app functioning and the improved health outcomes (Banner et al., 2013).

3.2.3 Security, privacy and regulations

Dehling, Gao, Schneider and Sunyaev (2015) studied the potential damage to users of apps through information security and privacy infringements. Their results show that more than 95% of assessed

mHealth and fitness apps (n=17,979) form at least some potential damage through information security and privacy breaches. They conclude that the collection of patient medical data requires extra attention in order to increase trust and acceptance by the different stakeholders. Appropriate measures and processes should be designed to ensure that end-users can benefit from medical app solutions without exposing themselves to security and privacy risks. Dehzad et al. (2014) mentions the lack of governance as one of the obstacles within the privacy and security field, currently there is no real supervision and app developing companies have almost complete freedom in what they put in the market. Another barrier that is mentioned here is that HCPs do not want to be responsible for possible implications of apps used in patient treatment, e.g. when HCPs fail to take the right action because of an incomplete picture of patient data through apps (Gagnon et al., 2015). A possible solution is the constitution of national standards for personal health records considering safety, privacy and accessibility to HCP systems. Trusted third parties could provide certification that indicates conformity with these standards (Boulos et al., 2014; Gallagher et al., 2015).

3.2.4 Integration and interoperability

One more barrier that is mentioned is the lack of interoperability with other systems. Often apps that are being developed are closed systems that do not connect with the HCP systems (Coöperatie Zelfzorg Ondersteund, 2014; Gagnon et al., 2015). A reason for this are the many separate HCP organizations, each with its own specific systems and processes. It is a big challenge for medical app developing companies to create an app that seamlessly integrates within work process of each individual HCP organization. Solutions mentioned are the definition of interoperability standards on a national level and the implementation of standardized platforms to connect apps using a uniform infrastructure. Collaboration between the different parties in the healthcare sector is required: having a dialogue on national level about healthcare innovation, to explore how we can continue to provide care in the with the help of technological innovations (Forman et al., 2014; Kumar et al., 2013; Nictiz & Nivel, 2016). Buijink, Visser, and Marshall, (2012) state: *"a shared decision-making approach in the creation of a regulatory guideline would both facilitate its acceptance among all stakeholders and enhance compliance to the guideline"*.

3.2.5 Individuals and experience

Often people are resistant to immerse themselves with new app technologies and HCPs have to cope with patients whom are not open for alternative treatment approaches. Patients may not see the additional benefits compared to current therapy management, prefer visiting the HCP in person or just have no joy in using an app (Scheibe et al., 2015). Besides, HCPs themselves may not be familiar with the different possibilities of medical apps and new technologies and are unable to provide the patient with the right support. Another issue is that people that do try using an app often stop after some time, a reason can be that apps do not stimulate use and some people do not want to be confronted with their disease all day (Katz et al., 2015). Actions that can overcome such challenges are related to increasing the awareness and motivation of an individual to use an app, for example through serious gaming elements. Also, if the app clearly reduces impact of a patient's disease on the daily life and improves the own insight on their personal health situation app use is considered more advantageous (Janssen, R., Bodenstaff, L., Gyaltsen-Lohuis, E., Haaker, T., de Haan, W., Krediet, I., ... & Hettinga, 2013). From a HCP perspective, HCP organizations could increase awareness through providing information and education for HCPs to increase the knowledge and availability of skills in the organization. The study of Nictiz and Nivel (2016) suggests to give more opportunities for HCPs to practice and gain experience on healthcare innovation related topics. Possible ways of stimulating HCPs are to allow more time for employees to immerse themselves and get acquainted with mHealth,

find ambassadors that motivate the stakeholders that are required for success and to visualize the results and outcomes (Nictiz & Nivel, 2016).

Something else that app developing organizations have to take into account is that digital and health literacy levels vary a lot. Boulos et al. (2014) refers to research which state that apps that are perfectly usable by younger persons, on the contrary might be very difficult to handle by older people or a disabled person with special usability needs. People need to be guided and might require some training to get used to an app and the functionality. In addition, young children or elderly often do not have a mobile device and might not feel for buying one just for their treatment needs (Schoffman, Turner-McGrievy, Jones, & Wilcox, 2013).

3.2.6 Financial

The last category covers the financial obstacles of implementing and using a medical app. Apps are costly and it is difficult to create sustainable business models. There is a need for trials with alternative reimbursement and compensation models, often there is no available budget for implementation in the HCP organization and reimbursement by health insurers is not yet available for patients, resulting in high subscription fees (Nictiz & Nivel, 2016). From a developer perspective, to increase the chance for compensation, it is important to have evidence-based results of the solutions you offer and have certification in place that indicates conformity with standards. To stimulate the generation of evidence on a medical app, HCPs should be allowed extra time to try out new app initiatives (RIVM & Nictiz, 2013; Wu et al., 2011). Providing a clear overview of the return on investment over time one can increase faith and trust of other stakeholders in the product, resulting in possible financial support.

3.3 The Dutch healthcare structure

The Dutch healthcare structure is ranked number #1 in Europe on the Euro Health Consumer Index (EHCI 2015) and is the only one which has consistently been among the top three of any European index over the past ten years (Health Consumer Powerhouse, 2015). The Dutch healthcare structure is characterized by a market in which health insurance companies act in competition and are separated from health care providers. The following chapters further explain the functioning of the Dutch healthcare system and how the different stakeholders relate to each other. An introduction is given on the role of m-Health which invades the current landscape and is finding a way to position itself in between the existing stakeholders.

3.3.1 Who are the stakeholders?

A simplified version of the stakeholders in the Dutch healthcare landscape is depicted in Figure 6 which is based on the model by Schäfer et al. (2010). The current structure exists since 2006. Every resident of The Netherlands is obliged to insure themselves and they are free to choose their health insurer as well as their healthcare providers. The government provides the input for the basic health insurance package and supervises quality and pricing of care. Health insurers are required to reimburse all care as stipulated in the basic health insurance package, but to attract patients they can compete on prices and offer complementary health insurance packages. Furthermore, health insurers are free to contract with healthcare providers based on the quality and cost of care that is provided by each health care professional. Healthcare providers compete on the quality of care for patients and on the composition of attractive care arrangements for health insurers. The Dutch Healthcare Authority (NZa), an autonomous administrative body funded by the government was established to supervise the Dutch healthcare market. The NZa sets rules and regulates health care providers and health insurers in order to provide transparency for the citizens (NZa, 2016; Schäfer et al., 2010).

3.3.2 Where does the developer come in?

Mobile healthcare solutions are developed to improve overall engagement with healthcare services. They provide a more efficient way of collaboration between healthcare professionals and patients to support the treatment process of a disease. Healthcare professionals can deliver more effective care whilst patients are given the opportunity to manage a greater part of the care themselves (Gallagher et al., 2015). In Figure 7 mHealth is positioned in the Dutch healthcare landscape which is represented by the medical app developing organizations.

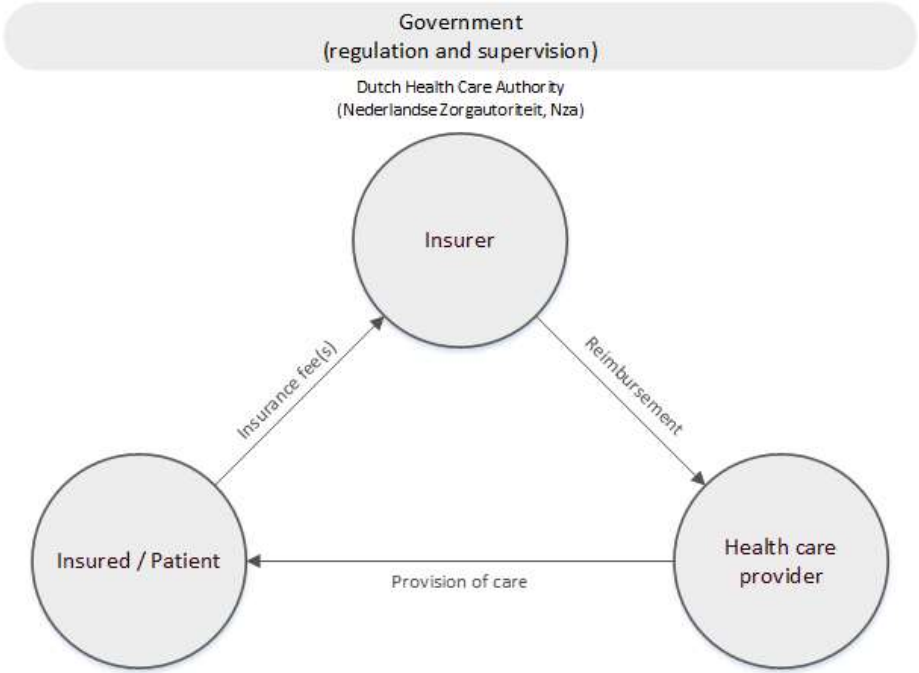

Figure 6: Dutch Healthcare system

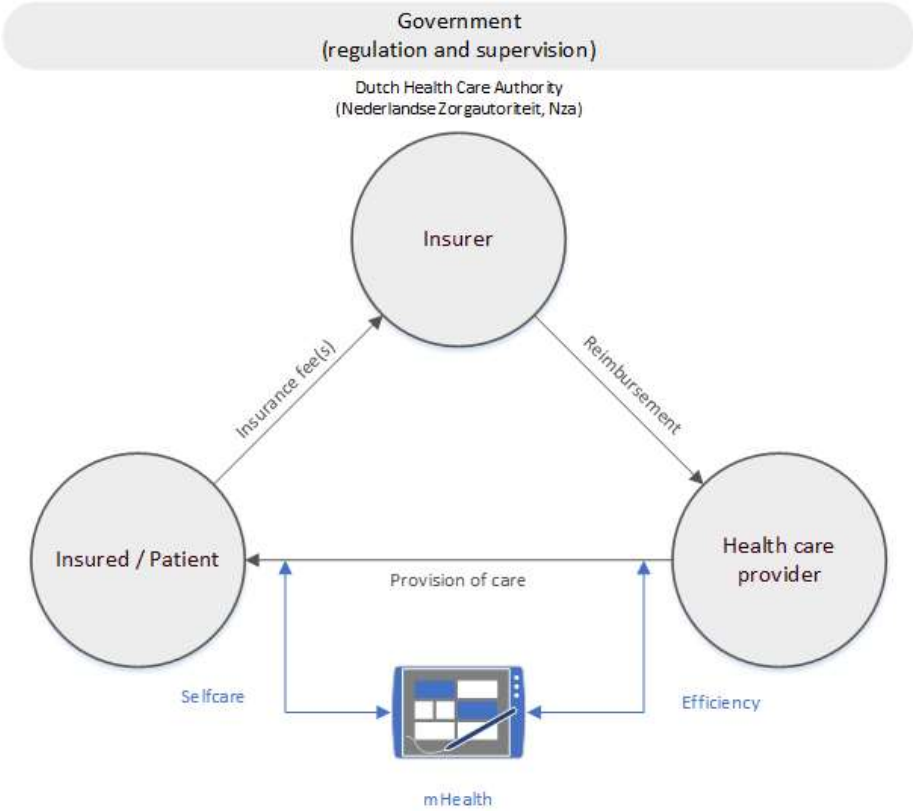

Figure 7: Dutch Healthcare system & mHealth

3.3.3 App selection and adoption scenarios

This section describes possible selection and adoption scenarios for medical apps based on the Dutch healthcare system that are derived from the literature and document study. We defined the below three scenarios that describe possible ways for app adoption in the Dutch market.

Scenario 1: The app is selected by patients or HCPs based on their preferences, and the app is reimbursed by the health insurer.

Scenario 2: The app is selected and reimbursed by the health insurer, and the app is adopted by patients and HCPs.

Scenario 3: The health insurer together with governing parties define the preconditions the app must comply with to qualify for reimbursement, and the app is selected and adopted by patients or HCPs based on their preferences.

Since the use of medical apps is relatively new and adoption is still low, scenario 1 is identifiable for the first phase in medical app adoption. Developers are fully engaged releasing new apps and the offer in app stores is growing every day. This enables patients and HCPs to try out new opportunities in the treatment of a disease, however finding the one app that best suits their needs seems a big challenge. Also, only few examples are available yet of apps that are reimbursed by an insurance company (Banner et al., 2013; Nictiz & NIVEL, 2014). Some of the big insurance companies in The Netherlands recently started funding projects that focus on self-care apps, scenario 2 (De Stentor, 2015). But why would an insurer be involved in picking a medical app? Shouldn't we leave this to those it is intended for, the HCPs and patients (?). Where we expect the app market to go in the next few years is the latter and fairest approach in which all app initiatives have equal opportunities for adoption. Given that not all good apps can be successful and widely adopted in the future, it is an interesting question how the market will develop. Although regulation on medical apps still lags behind, parties such as the ministry of health, patient associations, HCPs and health insurers start to collaborate in order to facilitate the process for medical app adoption (Coöperatie Zelfzorg Ondersteund, 2014).

4 Medical app adoption: barriers and solutions from expert interviews

In this chapter, we present the results of the interviews we conducted with experts that are active in the Dutch healthcare sector. Table 3 provides an overview of the interviewed experts. The columns represent an ID that is used as a reference method in the text, the role of the expert, the type of organization the expert is employed at, and the expertise or area in which the expert is active.

Table 3: Overview of the interviewees

ID	Role	Organization	Expertise
1	Product manager	Patient Federation	eHealth
2	CEO	Cooperation of patient groups representatives of primary care providers and almost all Dutch insurance companies	mHealth, chronically ill
3	Senior policy officer	Branch organization of healthcare organizations in nursing and homecare	Healthcare innovation, Information policy
4	Physician	Medium-sized hospital	Emergency physician, eHealth/mHealth/Apps
5	Diabetes consultant	Medium-sized hospital	Medical devices
6	General practitioner	GPs practice	eHealth/mHealth
7	Consultant	Independent E-health advisor	eHealth strategy, policy and product development
8	Policy advisor, medical advisor	Association of health insurers	Health policy
9	Senior advisor	Leading (big4) health insurance company	Care strategy
10	COO	Dutch market leader healthcare innovation and deployment of (home)care technologies	Development of Home healthcare innovations
11	Senior policy advisor	Dutch Ministry of Health	Mobile health, healthcare innovation
12	Senior advisor	Center of expertise for eHealth	Health and ICT, eHealth
13	Physician; CMO	Medium-sized hospital; Dutch market leader in medical app development	Urology, mHealth

During our interviews we have asked the experts to pinpoint what they believe are the biggest challenges for medical apps to find adoption. After they explained what they considered to be major challenges to app adoption, we presented them with a list of important barriers in recent literature (Table 2). In the next step we have asked the experts to come up with a top 5 list of barriers and to provide possible solutions that could help overcome these barriers. Last but not least, the 100 Dollar Test was used to get an idea of which obstacles the experts really want to be solved first. Experts were given an imaginary stack of 100 dollars and were asked to spend their money on solving their top 5 barriers. The mental process of spending money stimulated the expert to re-think about what really matters for them and emphasizes the items with priority.

In addition, we asked each of the interviewees to answer the below questions. Table 4 shows a summary of the answers that are discussed in the subsequent chapters.

Table 4: Expert opinion on compliance, certification and investment in healthcare innovation

Question	Yes	No	Not answered
Is compliance when using medical apps, a significant problem for you?	3	4	6
Do you think certification would help in the adoption process of a medical app?	8	0	5
Do you think medical apps will be the future of healthcare and would you invest in its developments?	12	0	1

From all the prioritized lists that were received, we started with writing down each individual barrier exactly as the expert described it resulting in a total set of 57 barriers to medical app adoption. From this list of 57 we have grouped same or similar results together resulting in a set of nine different categories. Based on the interview results we figured that the categorization of the literature findings in Chapter 3.2 was insufficient and therefore we have further specified and extended the categories. The matrix (Table 5) below shows the different barrier categories together with the experts hundred-dollar test outcomes sorted by occurrence. The column 'Average $ bet' is the rounded average of all expert bets together for that specific barrier: the sum of all individual stakes divided by the 11 experts that took part in the hundred-dollar test prioritization experiment.

Table 5: Barrier categories and expert prioritization matrix

Barrier category / Interview $100 Test results	Average $ bet	Interview 1	Interview 2	Interview 3	Interview 4	Interview 5	Interview 6	Interview 7	Interview 8	Interview 9	Interview 10	Interview 11	Interview 12	Interview 13
Funding	23		-	15	69		20	35	14	5	50	15	-	28
HCP willingness to change	16	25		25	10	10	25	15		30	5	20		16
Interoperability and integration	21	20	-		14		35		50		30	30		48
Digital literacy	13	10	-	15		30		40	14	35				
Quality based app overview	7	15	-			15	20		22				-	8
Co-creation	9	30	-	10	7	25						25		
Vision on healthcare innovation	5			35				10			15			
Evidence	3									25		10	-	
Privacy	2					20				5				
	100													

From the hundred-dollar test results, we can see that according to the experts the biggest obstacle for medical app adoption is the financial part, followed by the integration process and the willingness of HCPs to adapt their current work process to new innovations. The experts mention that most of the barriers are interrelated and solving one issue can be an incentive for solving another obstacle. In the following subchapters we will explain the barrier categories and for each category the expert feedback will be discussed and compared with each other.

4.1 Funding

Funding for innovations in the Dutch healthcare market is the most frequently mentioned subject among all experts (n=11) and is a complex challenge. It is not only about how to finance the development or implementation of a medical app initiative, but it also concerns the need for a clear business case and the creation of an ecosystem where new projects can thrive. However, the process for clear unambiguous financing where both costs and benefits are shared fairly among the involved stakeholders is still under development. From the two experts that did not mention funding in their barrier top-5, one (Diabetes consultant, 5) states that financial impacts may never be at the expense of a patient's care: *"It may never be the intention that the organization is the main goal. Many HCPs don't like change and are scared that it affects their profession, that they might have to change jobs because of new technologies. However, that may never be the key purpose, if your function becomes obsolete then look for something else"*. The other expert (Product Manager, 1) explains that right now there is no real financial barrier: *"There is no faith in a compensation plan for apps in the short term. If the product is truly good, patients will buy it. A trial version may help. Regarding the long term, a partial compensation by the insurer is conceivable and facilitates the adoption of apps"*.

The interviewed experts agree that innovation cost is a shared responsibility, but the involvement of so many different parties is what makes it difficult to speed up the process. For a correct understanding of the Dutch healthcare market and explanation on the financial flows between parties please refer to Chapter 3.3.

4.1.1 The lack of a business case

One of the experts (Physician, 13) describes the current financial situation as an innovation circle where both patients and health insurers are not willing to put money in yet. There is no clear responsibility for who pays what, distorting normal market functioning. Another physician (4) explains this circle as the feeling that the stakeholders are all waiting for one another: *"Health insurers first want me to prove that it works; I want to have some money first, so that I can prove that it works; the patient really wants to cooperate but does not really know whom to reach for; and the government says let the market figure it out".*

This misalignment between the interests of different parties also impacts the developers of medical app innovations. A consultant eHealth advisor (7) explains: *"As a developer of an app you have to be well prepared, you need to have evidence-based results and certification marks that indicates conformity with health, safety and environmental protection standards. It is difficult to get started, developers struggle in creating a business case and getting in touch with the right people"*. There are many great insights and opportunities by smart people that result in highly valuable products for the care sector, great apps that are or can be built, but most do not get through the funding discussions, the many laws, regulations and protocols. The COO (10) of a leading Dutch company in healthcare innovations adds *"The sales cycle in the care sector is very slow and extremely risk aversive. It is the culture and mindset that block the app adoption progress. Great parties with very promising ideas are already dead before they have seen the daylight".* Entrepreneurs, both small and larger seem to have difficulties finding traction in the healthcare market. Where small medical app developers, startups, have difficulties in finding capital to fund their ideas, the heavy weights have enough money to pave their own path but often lack the right vision and fail at creating a sustainable business model, explains the physician and CMO (13) at a leading medical app development company. He states: *"Innovation is not driven by large industries, but small startups"*.

A possible solution brought forward by multiple experts is to find enthusiastic people within the field, at insurance companies and the government, people who want to come along. Startups with great ideas should look for the innovators that think alike, open up the conversation to make a move and accelerate adoption. The COO (10) adds: *"We have to try out everything, different structures, alternative reimbursement and compensation models"*.

At the same time the Dutch Ministry (VWS) is trying to steer healthcare innovation in the right direction. A senior advisor Care Strategy at the Ministry of Health (11) explains they work on offering a HUB to connect all stakeholders and closing the circle, so that insurers are triggered to invest in tools. Through new funding programs they want to help HCPs to purchase apps and mHealth solutions and on the other hand facilitate insurers in the procurement process including these apps in their offering. In addition, he mentions another solution that will be a trial for a couple of years: *"There will be a digital health budget for citizens where they get X amount of EUR to purchase apps. They are offered a list of certified apps to choose from and we take the financial responsibility away from the HCP. This trial is to discover if, in this way, we could create an ecosystem for medical apps where the patient is in control".* The CEO at a selfcare supporting cooperation (2) substantiates this statement: *"We have to create a market that incites a new way of working, by setting a budget one can use to its own interpretation"*. Even so, the interviewed HCPs propose similar solutions where a patient gets a yearly budget to spend on medical apps. They mention that more and more patients want to be in control and that the patient-to-doctor conversation has changed from a patient that visits a HCP to hear from his professional judgement to a conversation where the patient tells the HCP what they have found on the internet and what they need to know (interviewees 1, 4, 6, 13).

4.1.1.1 Insurance money, its competitive structure

Health insurers, the party that reimburses the healthcare expenses to patients, or pays them directly on behalf of the patient to the HCP, explain that it is an edgy area. Expectations are that they also make investments in innovation and new technology. However, money for innovation or research is not on the budget of insurers. Insurance money, is money for which they have to deliver, that is what the client has agreed upon in the insurance policy. People pay their premium to make sure all medical care is well arranged and accessible. A senior advisor Care Strategy at one of the Big 4 health insurers (9) elaborates: *"We find innovation relevant, however we do not want to interfere with the HCPs business or with what patients want, that is their responsibility. We want to respond to their requests, we purchase care on behalf of our clients, and often people are not aware of that"*.

Insurance companies want the HCP and patient to think out the innovation, create a business case, then it is more likely the health insurer will respond in a positive manner. The senior advisor (9) states: *"If they, the HCP and patient find a particular app important, so does the insurer*". The health insurer is not the responsible party to think out the innovation, he continues: "*when entrepreneurs come to us with a great idea for an app, we refer them to this coalition of HCP and patient. If they back the idea, we want to join*".

We agree it is positive that the health insurer does not want to intrude with the care facilities, for decisions in this area must always lie with the care provider or its patients. However, it is interesting to see that they put a lot of weight on the need for a business case when a developer, HCP and patient approach them with the request to include an innovation in the insurance package. The advisor (9) explains: *"We are only tempted if, for example, you manage to arrange something with a large employer that allows us to create a collective group insurance policy. Not the other way around where people come say they have this great product ready and expect the insurer to sell it to that employer, that is not our work".* We can understand this scenario from an insurer perspective; they want a deal only when it offers an opportunity to win new customers. This clearly outlines the competition in the

market between health insurers as described in chapter 3.3; if they cannot distinguish themselves there is no benefit and therefore no reason to embrace app innovations.

A policy advisor at the association of health insurers (8), mentions that at local, regional and sometimes national level there are many successful app-related innovations funded by health insurers. However, what we see is that there are many separate initiatives for the same disease, which makes it difficult to agree on financial scaling and adoption on a national level. The expert states: *"The success of these separate initiatives is a barrier to the collectively scaling of apps on a national level*". Everyone is trying to build the next great app, insurers however cannot just support all initiatives without knowing whether the project is meeting the right requirements.

The competition between insurers in the Dutch market is the main reason for this fragmentation. Health insurance companies compete, particularly on large group insurances says the policy advisor (8): *"Apps and ICT-solutions are very popular to compete on and to distinguish themselves in their offering".* He indicates that collaboration would be a solution if health insurers form partnerships and opt for one and the same approach for funding and the procurement of healthcare innovations. However, he elaborates: *"If health insurers consider it competitive, equalization is not going to happen"*.

4.1.1.2 No room for trials

HCPs acknowledge that health insurers want to put money in, but they emphasize that for every tiny innovation the insurer first wants to be certain of the added value and whether it is going to save money over time. They feel there is no room for trials. A solution suggested by a General Practitioner (6) is to create leeway where HCPs can run a trial for a couple of months that gives the opportunity for a HCP to come with evidence that again motivate other people in the field. This is mentioned by the other two physicians quoted earlier. The physician (13) elaborates: *"If it is an innovative idea, say a HCP creates an app with developers to go to patients, it will reveal itself whether or not the developed solution makes sense. Governments and/ or insurers should encourage these trials"*.

It is interesting to see that insurers say there are many app ideas already funded and reimbursed by health insurers, while the experience of HCPs is that the request to run trials in collaboration with insurers is not answered. This discrepancy could be explained by the fragmentation issue as described by the policy advisor (8) at the association of insurers. Due to the many apps available in the market that often serve same or a similar purpose, it is very difficult for the insurer to decide which to focus on. What we see from the different expert explanations is that some HCPs do like to start trials for app initiatives, but the insurers want to reduce the fragmentation, and therefore don't want every HCP to start experimenting by themselves. Bringing these together, it could help if HCPs join forces, and realize an idea together. When insurers see a great product that is supported by multiple HCPs and patients, they indicate that they are happy to join the conversation.

4.1.1.3 Investment in technology cuts in HCP turnover

One of the experts, consultant eHealth advisor (7) states: "Project and investment costs are a major obstacle for HCPs. Healthcare organizations need a clear business case from which one can see the return on investment over time". A senior advisor at the Centre of expertise for eHealth (12) elaborates: "The way in which healthcare is currently funded works counterproductive. There is no reward for improving care using smart innovations, in fact healthcare professionals get cut in sales". One of the biggest bottlenecks for app adoption in the current system is that HCPs get paid for each treatment given to a patient. When a hospital or HCP invests in new technologies like self-management apps, patients are expected to improve in the self-management of their disease. Since they are more self-regulated, they visit less often the hospital, which leads to a decrease in billable

treatments for that HCP. The health insurer eventually walks away with the profit as the healthcare costs decrease.

This puts pressure and time constraints on HCPs to meet the targets set by the hospital, with the outcome that none of their time is spent on innovation. A physician (4) explains: *"We do not benefit financially from fewer daily appointments. Imagine the technology is fantastically tuned to the patient, I get 15 patients instead of 60 because the rest of them is self-regulated. We will get paid for the 15, not for 60, thus a loss of income"*. Instead, it is important to give space for doctors to experiment with new technologies and put the emphasis on health: focus on the number of patients that did not need to visit their HCP because of improved selfcare facilities. Some physicians do want to step out their comfort zone and try new things, but often do not get the opportunity to do so. The physician (4) states: *"Ideally, I spend 10-20% of my time locked up in a room and think out something great, but I deliver a lot more money if they put that 10% on a broken ankle or wrist"*. Yet another goes even a step further and mentions that if they need to make more money, they just shorten consultation hours and receive more patients.

The interviewed HCPs however agree that we should focus on health instead of illness. The problem right now is that we do not choose for 'the best care' but we go with what is the most profitable approach. This obstacle is caused by the current system and requires redesign of the process in which multiple stakeholders should share the same vision. A solution starts with aligning the different parties explains a policy advisor at the branch organization of healthcare organizations in nursing and homecare (3): *"By putting the different stakeholders around the table, make a plan to do joint investments and moreover share the savings among all parties, it is more likely to become a success"*. The CEO (2) also mentions we have to step away from a pay-per-treatment approach: *"We need to establish a new way of care working, not only focused on the treatment, but to support the patient in his own activity. Don't pay HCPs per e-consult or app use, but give budget to work differently using new technologies"*.

Both the senior advisor (12) and the consultant eHealth advisor (7) suggest that agreements with insurers can be made on shared investments, where the insurer covers part of the decrease in HCP income (loss of sales) after the commissioning of an selfcare app. Set a ceiling and guarantee an amount of money for a certain period. In this way we stimulate entrepreneurship and focus on innovation results that bring savings for the HCP. For example, expected savings because of using medical apps in the care process is 20-40 percent. If in a normal situation they get X money for a single patient treatment, now the insurer gives them 8X budget for every ten patients they treat. Pushing them to use more innovative solutions so they eventually can keep money in their pockets.

The Dutch healthcare structure is a lot more challenging compared to other countries. Profits should be a social shared profit explains the COO (10). He explains: "*However, in the Dutch model, insurers are in charge. Other countries have different structures where the executor and financer are the same party, if you invest money and save costs as a result there is no need to think twice"*.

The advisor (12) ends with: "We need to do this together, you cannot innovate the care sector on your own".

4.1.2 Unfamiliarity with available budgets

Professionals working in hospitals mention that budget for innovation is important to try out new things like apps. However, although they have heard of available innovation budget in their organization, they do not know where to get it and the process seems unclear. A physician (13) explains *"There is a piggy bank for innovation, but it is not clear, and I have no idea where to get it"*. Innovation budget is a key incentive and it needs to be clear what, where and how doctors can claim this.

4.1.3 No hours for innovation

Time is money. In addition to the unfamiliarity with available budgets in the organization, another thing that all interviewed HCPs mention is that they do not get any hours to work on innovation. If they do, it is in their own time. The physician (4) explains: *"Ideally, I spend 10-20% of my time locked up in a room and think out something great, but I deliver a lot more money if they put that 10% on a broken ankle or wrist"*. Reimbursement of (extra) time to try out new app initiatives could give a boost to HCP willingness to work with new technologies. Another often mentioned solution is accreditation. HCPs have to reach their yearly targets for accreditation points, which they get for following courses and attending congresses. However, no accreditation is given for healthcare innovation like subjects. As a result, what we see now is that there are only a few enthusiastic physicians, putting in their own time, there is some subsidy grant or a research project, but no hours are granted for exploring medical app use cases.

4.2 Healthcare professional willingness to change

The second-most-mentioned barrier (n=10) is the willingness to change working standards of healthcare professionals, which strongly relates to all the other barrier categories. In other words, solving other barriers is likely to impact the willingness to change in a positive way. For example, when there is a clear quality standard regarding mHealth apps (barrier 3), healthcare professionals may be more inclined to adapt to high-quality apps, opposed to making an uninformed decision.

4.2.1 Conservative culture and mindset

Healthcare professionals are resistant to immerse themselves in the adoption of mHealth innovations. Although there are many initiatives, there is no collaborative approach where HCPs work together on the implementation of a specific app. Apps are not yet seen as an important tool in treatment processes. A physician (4) argues that doctors often stick to their tried and tested methods: *"HCPs stick to methods that do not incorporate newer techniques such as a new proposed medical app*". In other words, some doctors are conservative in changing or improving treatment methods. The diabetes consultant (5) supports these claims: "*HCPs have a conservative attitude; an example is that many still prefer to receive data via old fashioned e-mail instead of a fancy platform or app".*

The COO (10) explains that within many areas of medical expertise, the contemporary culture and mindset hinders innovation. He elaborates: *"People start their studies, finish their studies and already know what they will be doing at the age of 30, 40 and 50. Healthcare is one of these very risk aversive areas. Many protocols are in place and everything is documented in utmost detail".* The advantage of such protocols and documentation is a very small (critical) error rate, which is especially important in the medical sector. However, there should still be room for (mobile) innovations, which such protocols currently prohibit.

Currently the work of HCPs is controlled by several different supervisors, and new innovations must be clinically and legally tested over a time span of over a decade. The COO (10) mentions a solution where HCPs are given more time for (medically related) trials: *"let them test new apps without*

knowing the exact outcome upfront, we need a learn and improve approach". The General Practitioner (6) also mentions something similar, but with more emphasis on work pressure: *"We need to create leeway so that everyone is able to run trials without risking the possibility of not meeting targets"*. Parties who can stimulate the HCP to spend more time on trials are the professional organizations and health insurers, which can be realized by encouraging doctors through accreditation. People need to be rewarded for trialing new innovative approaches instead of punished by protocol-led supervisors. The COO (10) believes that more space for trials can really be a factor that influences adoption and adds: *"We as a company active in healthcare innovation try to stimulate the different stakeholders and keep asking questions about the how and why apps could be of added value"*.

The senior advisor at one of the Big 4 health insurance companies in the Netherlands (9) indicates that HCPs have the lead in medical innovation and can either make or break them. The question is how important innovation is to HCPs, and how much they are willing to change. The Senior Advisor cites: "*If they want to use certain medical apps, and form a coalition with other HCPs, then health insurers are also willing to come aboard. Hence, it is important to show best practices initiated by HCPs*".

4.2.2 Change in work process

Apps are often very complex and incompatible with standardized HCP work processes. Implementing a different workflow takes a lot of time, as the General Practitioner (6) cites: *"Initial setup takes a lot of time, however after implementation the benefit can be of great value"*. A physician (13) mentions that doctors are not likely to implement new innovations because they interfere with their work routine. The consultant eHealth advisor (7) elaborates: *"HCPs are continuously under pressure and hospitals require a high number of patient visits. They [HCPs] need some time and space to stop and think for a while about how they could provide care in a different way"*. That time is often not available during normal business hours, so if one wants to work on innovation, he or she has to invest his/her own free time. He continues: *"It is always 'additional' work, not 'instead of' something else*". Implementing an (app) innovation always requires an investment in time. HCPs need to familiarize themselves with new workflows and (digital) products. However, the consultant explains there should be a responsible person for supporting the implementation process, preferably someone who is active and recognized within the specific department.

Change management is needed to demonstrate that the technology really facilitates doctors and patients, and makes both of their life easier. However, problems arise because doctors don't have much time per patient. Given the current workflow standards, doctors work in efficient and effective routines, and innovation would require them to deviate from such efficiency and effectiveness. The physician (13) states: *"These people are not willing to invest, they are not entrepreneurs*". He indicates that change can be made by finding both ambassadors and written evidence from medical literature: *"Apps must be proven for the HCP, have peer reviews. If the apps meet all the requirements, then you can persuade people to experiment with it*".

Another obstacle mentioned by the senior policy advisor (3) is that HCPs also have to cope with resistance from patients whom are not open for alternative treatment processes. She illustrates: *"Often, we do not think of the social matters, patients that enjoy the time a doctor comes along to visit them. However, reimbursement of healthcare costs is only available for real treatments, not for a cup of coffee and a nice chat on how the patient is doing*". We have to find the right balance for each interaction between patients and HCPs.

4.2.3 Lack of knowledge in the field of mHealth

Healthcare providers do not stimulate the use of mHealth applications amongst their patients, because they lack knowledge in the field of medical innovation, says the product manager at the patient federation (1). The diabetes consultant explains that in order to convince HCPs, they first need to experience the added value of innovative solutions.

Innovation in practice is often about improving a product or process. However, according to the senior advisor (9), real innovation is needed on the social and information level, these are fundamental for product and process innovation. There is a lot of skepticism: *"we are busy creating a new product for years, but it does not work because in the end people do not want to use it*". Insufficient time is invested into the social and information innovations. HCPs need to be trained in order to make them understand new products. Currently, there is no incentive, says the senior policy advisor at the Dutch Ministry of Health (11): "*being an HCP you have to believe in innovation, and be eager to familiarize yourself with the technology, otherwise you are not going to do it"*. He adds that the Ministry of Heath could be of more support by spreading evidence of the added value of medical apps: *"We need to provide insights on the advantages and (financial) benefits of using new technology*".

A solution mentioned by the product manager (1) is a platform which has an overview of the best apps that are supported by all stakeholders. The platform should include a ranking system and quality control system to facilitate HCPs in finding suitable solutions for their (specific) patients: *"When a doctor nudges you to use an app, patients will make the transition to use the app far easier"*. Furthermore, HCP must be supported both financially and in time to make it attractive for them to work on app innovations. The physician (4) illustrates: *"In the ZorgICT fair, a symposium about technological advancements in the healthcare field, there were almost no doctors present"*. Currently doctors must get a certain amount of accreditation points per year, which the spoken-off symposium did not provide. A solution for this problem would be to accredit points for medical technology symposia as well. In such a scenario, doctors would be introduced to new technological advancement, which subsequently might result in better adoption. This is proven by another symposium organized by Mobile Doctors, a Dutch innovation platform in healthcare, which offered visiting HCPs accreditation and attracted many doctors. The physician mentions that conference organizers can request the provision of accreditation points for a small fee.

4.3 Interoperability and integration

Incompatibility between different systems is considered another barrier among the top 3 most frequently mentioned (n=8) by the experts. For the average doctor, implementation has to be relatively easy and require little effort, one of the experts explains (6): *"doctors are not going to spend half a day of their own time on the implementation of some medical app or wearable, instead it must be up and running in half an hour*".

The integration phase is one that often encounters some problems during the implementation of new technological solutions such as apps. Communication is key and is important to manage the expectations of the different parties involved, says the COO of a leading Dutch company in healthcare innovations. The COO adds: *"If a new product does not work a few times for a patient or HCP, this could lead to skepticism*", resulting in people ceasing usage of the app. At this moment mHealth and app adoption is still at an early stage, we are all learning and it might take several years before a stable ecosystem is in place (10).

4.3.1 Stand-alone (closed) systems

More than once, developers of medical software like apps and electronic health records build stand-alone (closed) solutions (interviewees 1, 4, 8, 11). In other words, other applications will not be able to use data provided by such closed systems. The policy advisor at the association of health insurers (8) clarifies: "Hospitals*, GPs, pharmacists, all have separate information systems and the bottleneck is that these systems do not communicate with each other"*. A General Practitioner (6) mentions 'integration with legacy systems' as another issue: "*my HIS (GP information system) cannot do anything with the data of these medical apps"*. These discrepancies in systems can be caused by a lack of standardization between the different applications. In other words, the application programming interface (API) is considered to be closed. Instead, a physician (4) argues that *"systems should provide open public APIs in order to communicate with [other systems]"*.

4.3.2 Inefficiency of the current system

This lack of compatibility between systems causes inefficiency, for doctors, pharmacists, and other professionals are not able to directly review a patient's medication overview. Instead, the physician (4) explains that the complexity of exchanging data within the hospital is very high: *"A doctor that would like to review a medication overview asks for a nurse to do the request. The nurse would have to call the pharmacy Servicedesk, the Servicedesk makes a call to the pharmacist and the pharmacist would have to need the patient's signature that will be sent via fax. Only then can the pharmacist share what medication the patient has been using. The overview is printed by the pharmacist and they send a scan, again by fax, to the nurse who made the request. The nurse eventually scans the fax to add it to the file of the doctor"*.

This brings us to the next obstacle, as scans are usually not of great optical quality. The physician (4) continues: "*When I fax something, a scan is provided in which I cannot see the difference between a six, a nine or an eight*", which endangers the patient. A slight difference in drugs dosage or misreading test results can be significant, impacting the diagnosis and the appropriateness of doctors' advice (McGrath, Skinner & Morgan, 2014).

Another example is when an electrocardiography (ECG) is created by a patient's general practitioner. When that GP would like a cardiologist to take a look at the result, this process may take up to four hours through traditional communication protocols. This is starkly contrasted by the time it would take if the same request is done through KPN I Care, an information sharing platform: 20 minutes (4).

4.3.3 Dutch law hinders interoperability

The lack of interoperability is not just caused by poor system design, but also by Dutch law. The Dutch Financial Markets Authority (AFM) restricts any firm from obtaining an unfair competitive advantage. This prevents the hospital's pharmacy from gaining insight into another pharmacy's system. By extension, this creates a barrier for the creation of an application where such sensitive information is created and shared.

4.3.4 Limitation to reach new customers

The policy advisor at the Ministry of Health (11) explains that when connections are not provided to other systems, as a developer reaching new customers will be very limited: *"You offer a product, people have to buy it from you, but already have other systems in place, how is it going to help them if they cannot integrate the solution in their current process?"*. If you do not define the interoperability standards upfront and do not provide a connection with the professional systems of HCPs, there is still a lot of manual work to be done. As a result, HCPs will not likely be to use the solution since they have to do something 'extra'.

4.3.5 Interfaces and uniform infrastructure as a solution

The suggested solution is that data between different patient health records should be transferable under certain conditions, and maintainable by patients in a single platform. This will allow the patient to create a unique health record that incorporates all useful data. The patient can be in control and by doing so we take the hurdle away from HCPs (4). A policy advisor at the association of insurers (8) explains that they are currently working on interfaces, using a standardized way for exchanging data. At the moment few Personal Health Environments (PGOs) are available to improve data exchange, however, the interconnectivity between platforms and systems is poor and linking these together remains a challenge. As different infrastructures are used to exchange data, a solution could be the creation of a uniform infrastructure or having different architectural layers communicate with one another via APIs. The information council set up by the Ministry of Health, which is represented by all the different stakeholders, are responsible for discussing and providing nationwide integrated solutions. In addition, we see an increasing amount of alliances (hospitals, HCPs, patient federations, etc.) that start to work on developing solutions for existing integration barriers.

A physician (13) states that HCPs can help in guiding patients by recommending initiatives that meet interoperability standards: "*Standards as described by regulatory authorities must be acknowledged and we have to maintain these guidelines*". In addition, he mentions that patient federations could convince patients not to participate in the proliferation of medical apps, but steer on app guidelines and platforms from recognized parties.

4.3.6 The app in a greater ecosystem

Apps needs to be part of the everyday life of patients, but also part of the workflow of HCPs, says the CEO of the Dutch leading self-care supporting cooperation (2). He explains: *"HCPs find it a necessity to have a link in place between the app and their Healthcare Information System (HIS). However, these legacy systems lack APIs and therefore, connecting the many separate apps to a HIS is a challenge"*. As a solution, platforms are being build which can connect with the HIS, and subsequently the medical app is connected to this platform via an API. With such a construction, we can create connections with other healthcare databases and online health environments. The CEO adds "*I don't expect to see a single platform for all medical apps, instead I see multiple platforms being created, used next to each other, simultaneously and interconnected with each other*". The COO (10) has a similar opinion and foresees a solution in the creation of an ecosystem with a hub and spoke system: hubs (platforms) that will integrate the different mHealth technologies (apps) with the different HCP systems.

An example of such a platform is 'MedMij'; a personal healthcare environment that collects all patient data. This includes input from HCPs, medical devices and wearables. Moreover, MedMij has an option which allows the patient to determine with whom they want to share their data. The product manager at the patient federation (1) elaborates: *"these platforms set the conditions and apps that are offered through the platform all comply with the same standard allowing the safely exchanging of medical information".*

4.4 Quality based app overview

Another barrier is that people cannot find the right app for a disease in the mass of apps that are available in the app stores. We often talk about losing the forest for the trees, but one also loses a tree within a forest: how can you, as a patient, find the right app that suits your disease (6). The yearly eHealth monitor (Nictiz & Nivel, 2016), a recurring research on the state of healthcare innovation shows a decent increase of new apps in the app stores. However, mass adoption still lags behind and there is no central place for people to find detailed information of available apps, explains a senior advisor at the Center of expertise for eHealth (12).

4.4.1 The HCP ambassador

A physician (4) and a senior advisor at the center of expertise for eHealth (12) both mention that doctors could take the lead in this by recommending apps to patients they already use and have proven useful. However, this is in contrast with other experts who mention that HCPs seem to face a similar issue: they have no idea what to use out of the current app offering. The senior advisor at the association of insurers (6) elaborates: *"if your GP wants to advice you on a self-management app, what should that poor man or woman choose from, how do they know that they recommend something that is of good quality?"*. The GP (6) mentions that he would like to suggest apps to patients, yet he has to ensure that those suggested apps meet a certain quality standard: *"I have no accurate overview of available medical apps, and it is very unclear to me which apps are valid and reliable"*. A diabetes consultant (5) has a similar opinion and explains that there is a lack of transparency: *"How do I know that these apps are good and safe to use, the data is not used for any other purposes like sharing with insurers or other parties? I will not recommend an app if this is not clear to me"*.

4.4.2 Funnel available apps

A reason for the huge number of available apps but low adoption, is the so called 'not invented here' syndrome: although there are tons medical apps available, still everyone wants to create their own thing. The physician (13) mentions that we have to focus on limiting the number of high quality apps and get these accepted by a larger audience. He states, *"some diversity is good, but currently the offering is too big, and people don't know what apps are good and reliable*". A solution would be to introduce laws that push app developers to comply with standards and force them to have the right certification marks for their products in place (6). The physician (13) adds to this solution: *"If you want to be accepted in the ecosystem you have to make sure that your product is compliant, if not you risk a fine"*. Once we filter out the apps that meet the standard requirements, we can investigate whether the app contents are of sufficient quality and whether it is proven useful in the treatment process of a patient. The Royal Dutch Doctors Federation (KNMG) and the National Patient Federation (NPF) have come up with such a set of requirements. If developers comply they will be given a specific medical app quality mark. However, the senior advisor at the association of insurers (8) believes that there is still a major obstacle; even though apps comply, the challenge for the individual patient remains: 'who should I ask for advice' and 'what should I look for' in the selection of apps. Patients have difficulties in seeking advice, because often they already use an app for a disease before the HCP is aware of the innovative solution.

4.4.3 Platforms as a solution

Platforms that list the apps that are approved by the governing parties would be a first step to overcome this barrier (1, 4, 8). The next step would be a ranking system where both patients and a group of HCPs can rate their favorite apps. In this way we can create a database of qualitative apps where the individual HCP does not have to spend time on analyzing huge amounts of apps. Instead he or she can advise patients with confidence based on the research of other colleagues that is available through reviews in the platform. The GP (6) elaborates on a useful implementation: *"offer the compliant apps through a platform where doctors can turn on/off app modules per patient"*. Examples of such platforms are the GGD Appstore by the Dutch Public Health Service or SynAppz developed by a Dutch market leader in medical app development. The senior advisor (12) explains "*These platforms list the top 10-20 apps per illness, which is a manageable number to provide expert feedback on*".

Last but not least, when platforms are in place, the CEO (2) mentions that the next question is "*how you reach the bigger audience?"*. Via platforms, apps should be able to reach large groups of people if the available platforms are communicated to end user through different media. The product manager at a patient federation (1) mentions that parties such as patient federations, healthcare institutions,

HCPs, but also national campaigns and app awards could contribute to the awareness. The Diabetes consultant (5) indicates that it is not easy to introduce these new innovations to HCPs and adds: *"hiring key opinion leaders to share their opinion on an app or platform could increase confidence among HCPs*". To draw patient's attention to platforms the senior advisor at the association of insurers (8) explains that it is useful for developers to involve health insurers in experiments with new platforms at an early stage. This, because the health insurer is likely to include products that connect through the platform in their offering to patients, especially if such platforms target a specific group of patients, a municipality or region.

4.5 Co-creation

With the term co-creation we refer to app developing companies working together with relevant patients and HCPs in order to synergistically create useful mHealth apps. The CEO (2) mentions that only a few good self-management apps are currently available. One of the reasons is that developers start with a great product in mind, build something, and subsequently make it available through app stores (such as Google's Play store and Apple's Appstore) without including the end-users/patients in the development process. The diabetes consultant (5) mentions that many apps are very cumbersome, and as a HCP he wants an overview of patient's measurements with a single button click. Instead, patients still need to bundle data themselves and sent it to the relevant HCP. The eHealth consultant (7) explains that he is still amazed by the number of cumbersome apps that are being developed. However, if you want your app to find national adoption, it should be of extremely high quality. He advices a LEAN development approach for startups: *"if you are a startup, it must be part of your DNA to be very focused on your target group, you should be constantly measuring and improving the product based on end-user feedback"*.

4.5.1 Developer – patient relation

A product manager at the patient federation (1) mentions that the biggest obstacle they face is that many apps that are being developed do not meet the patient's expectations: *"often patients need to use multiple apps for one purpose; the perfect app does not yet exist"*. The developers do not sufficiently involve the patients during the development phase, resulting in apps of moderate value. The senior policy advisor at the ministry of health says, *"It is all about the patient, developers should connect with them in the development phase"*. The CEO (2) explains that apps should tempt (i.e. nudge) patients to work on their health. If the app does not reward the patient in the care process, patients will probably stop using the app. To overcome the obstacle where developers create apps which are not aligned with their users, the senior policy advisor (3) mentions that developers need to start thinking like a patient: *"[the developer] should be able to seamlessly integrate with the end user's requirements, the specific needs they require in their care process to improve the quality of life"*. The solution here is co-creation between developers and patients. The product manager (1) states that more congresses should invite patients, which is one step to encourage co-creation: allowing both developers and patients to collaborate on new innovations.

4.5.2 Developer – doctor relation

The physician (4) points out another obstacle: collaboration between doctors and the developers. On one hand, doctors are often not familiar with the different applications available, while on the other hand developers cannot get in touch with the right HCPs. He explains: *"[The developers] are often redirected towards the ICT-department of the hospital, while they want to know what's going on at the floor by speaking with the doctors themselves"*. The solution here may seem familiar: doctors and ICT developers of medical application need to be brought together. One way to realize such

collaboration would be to incentivize doctors to go to medical congresses by awarding them with accreditation points (4).

4.5.3 Developer – health insurer relation

In addition, it is important to involve the health insurer in the development process. In early stages, developers have to think about what content they want to offer and whom is going to pay for it (7). The senior advisor at a Big 4 health insurance company (9) explains that from an insurer perspective, an app requires a proven track record before it can be recommended to customers (i.e. patients): *"we like to know to what extent [the app] positively affects the efficiency and effectiveness of healthcare"*. If a health insurer is involved from the start of the development process, it is more likely that their requirements are implemented, which in turn increases the changes of reimbursement for patients.

4.6 Digital literacy

Groups of low social economic status often have little involvement in innovation and have difficulty with change: *"these people are not likely to use new technologies because they are anxious of changing their habits*" explains a senior advisor at a Big 4 health insurance company (9).

4.6.1 Unfamiliar with possibilities

The policy advisor at the association of insurers (8) mentions that at the moment many people lack knowledge on the possibilities of mHealth: "*people don't know what can be done in the field of medical apps, or what the possibilities are with their HCP. There is a lack of information provisioning, which is a bottleneck for app adoption"*. The eHealth advisor (7) explains that many people have a poor digital literacy, i.e., they have not been exposed to necessary education and/or experiences with mHealth technologies, thus resulting in insufficient knowledge on potential innovations in this area (7). The diabetes consultant (5) mentions that many patients do not even use a smartphone yet: *"they have no idea how the technology works"*. Additionally, he explains that there is not much demand from patients in mHealth apps. Instead, people tend to stick with old-fashioned e-mail. In the end, if apps are to find national adoption, the demand should come from the consumer side: *"we need [patient] to start indicating that they find this very important"* (9).

4.6.2 User authentication barrier

People sometimes do not comprehend the process or technology. For example, one of the most mentioned obstacles using apps is user verification. Apps often store confidential patient data and therefore require users to create an account and login with a username and password. This can be very time consuming and a major barrier for people who want to use an app. Furthermore, elderly or low-educated people may often find it difficult to understand underlying security measures, such as e-mail verification or two-factor authentication (interviewees 1, 2, 3). However, the CEO (2) believes that these issues will be resolved in the future, when new (more convenient) online user verification technologies become available.

4.6.3 Social innovation

Other experts argue that not all people are against new technologies, instead many people want innovation, but a large group have difficulties with the unfamiliar. People need to be guided and require some practice before they understand how to use an app and associated benefits (interviewees 3, 8, 9). The senior advisor (9) suggests that there is no 'one size fits all' approach: *"we need social innovation, we have to think about how to introduce new innovations in health care within different socioeconomic groups*".

The senior policy advisor (3) explains that she experiences a lack of vision and support during the implementation phase: "Innovation needs a collaborative approach of guiding and supporting the users through the process, instead of just handing over a new solution". She mentions that the technology has to be really easy to adopt, which requires the developing party to go through development stages together with the end user (co-creation): "at the moment technology is being developed by young men for old woman, it doesn't work that way". The diabetes consultant adds that apps have to be fool proof, even for dummies: "If my patients want to share their glucose measurements, testing blood sugar as usual and pressing a button once or twice a week before meeting with the doctor should be it. Nothing more, nothing complicated".

The majority of experts believe these issues will resolve over time, as more technologies are included, improved and explained in contemporary education. However, solving such issues does require a different way of working and thinking, which is a hindrance for the current generation (interviewees 2, 3). Another solution mentioned by the eHealth advisor (7) is to give employees adequate credit for time spent on innovation within organizations and providing training on relevant subjects. Current training institutions should increase their offering of courses, and healthcare organizations could stimulate their employees to literate themselves in the digital age (7).

4.7 Evidence

The senior advisor (12) says *"Lack of evidence is mentioned in many articles as a main reason of slow adoption/implementation"*. As more selfcare apps reach the market, professionals wonder whether they are safe to use for their patients (interviewees 4, 9, 12). Once the technology becomes part of the regular healthcare process, HCPs want to know what is happening inside the black box. The senior advisor at the center of expertise for eHealth (12) explains that in terms of evidence, medical app usage differs from traditional medication. For example, new medication requires years of research before doctors can prescribe it, whereas apps are developed much faster, updated over time and generally have a shorter life-cycle.

4.7.1 Need for research experiments

Currently there are few studies available on app effectiveness (e.g. remote heart monitoring) that clearly show the effect on number of incidents, hospital admissions and communication improvements. Nevertheless, the senior policy advisor at the Ministry of Health (12) argues that the threshold for hospitals to implement new technologies is very high: *"There is a lack of good figure on the real added value of implementing the medical app. Economically, financially but also in terms of quality and health, how many hospital beds does it really save?"*. To provide answers to such questions, faster validating procedures than randomized controlled trials are necessary. The average lifetime of an app is short, and exciting apps are updated every few months. The senior advisor (9) states that sustainable use is often poor: *"If more research would be done on sustainable use of app solutions and the added value for consumers, apps would have a greater chance to be accepted and successful*". However, app developers often cannot afford the cost to both launch a product and also scientifically proof its added value. The senior policy advisor (12) indicates that the Ministry of Health is working on the creation of a process where developers can demonstrate the viability of a product in a short timeframe. He states: *"Right now the process of creating a minimal viable product is so slow that many opportunities are missed"*. The senior advisor (9) also mentions the problem of insufficiently substantiated evidence of apps: *"There is a tsunami of new initiatives, but the evidence, does the solution work well, is still moderate"*.

4.7.2 Trustworthiness of data

A physician (4) mentions that some doctors find it hard to rely on data provided by medical devices, a point which is often raised when discussing the implementation of a new solution. A refutation, often mentioned by proponents of healthcare innovation, is that existing home measurement methods lack accuracy. He illustrates: *"if we ask patients to weigh or test their blood pressure two or three times per week, we don't know if the data is trustworthy"*. Self-care data is generally trustworthy when HCPs are looking for trends in the values, as obvious outliers can be easily excluded (e.g. the increase and decrease in blood pressure). With more critical data, HCPs might need exact values for which selfcare data is less viable, as individual values will require different interpretation for patient A compared to patient B. The physician (4) believes that the issue is mainly with HCPs, he states *"I think that the patient easier trusts the device than we do as a doctor*".

4.7.3 Introducing certification

On the question whether the experts envisioned certification as a positive contribution to the adoption of new medical apps, all of them answered yes. Although some experts mentioned that complying with a standard can result in a lot of additional work for start-ups, they also mentioned that such a threshold would separate the wheat from the chaff: it helps high potential and qualitative apps to stand out in their journey to adoption. The senior advisor (12) states: "*There is too much growth making it very hard to regulate the supply, certification marks could help"*. A well-known certification mark for products sold in the European Economic Area (EEA) is the 'CE' marking, which indicates conformity with health, safety, and environmental protection standards (EUR-Lex, 1993). However, the senior advisor (12) explains that the CE marking looks at very general points. Hence, it cannot immediately give an indication on the added value of any mHealth app. Currently experts are still undecided on whether a single national standard is needed opposed to multiple variations. On this topic, the senior advisor (12) has a very outspoken opinion, as he clearly does not believe in a single national standard: *"I do not expect a single quality standard for the Netherlands on a national level, the market effect* will result in a shortlist of compliant apps that remain.

4.8 Vision on healthcare innovation

Making the transformation to a new care process with multiple stakeholders involved requires a well concerted and agreed upon vision. The eHealth consultant (7) explains that we currently lack such vision and innovations are seen as separately stacked elements. People tend to stick to the regular care process: *"Currently what we see is that people add eHealth as extra to the current process instead of changing the actual treatment approach".* He advises that the existing care process should be the starting point for digital transformations. With the existing process in mind, stakeholders can design alternative approaches and discuss on how to implement new treatment offerings for patients (7). The senior policy advisor (3) mentions that we have to keep our eyes on the future, and stresses the importance of communication between parties in the healthcare sector (HCPs, insurers, developers and governmental organization): *"It is important to have a dialogue on both regional and national level about healthcare innovation, to explore how we can continue to provide care in the future with the help of new technologies"*.

4.8.1 Differentiation in HCP standards

The COO of a leading company in the development of healthcare innovations (10) explains that medical app developing companies often have difficulties in connecting with all relevant stakeholders. There are many separate HCP organizations (also referred to as silos) in the market, each with its own specific systems and processes. This is a challenge for developers who want to implement solutions with a uniform structure: *"As a developer you have to push all the relevant stakeholders in the same*

direction". On the other side, this means that HCPs can facilitate the adoption process of new apps and solutions by integrating HCP standards with other HCPs: *"They [HCPs] should try to create a seamlessly functioning healthcare network, using a single standard for systems and processes" explains the COO*. He mentions that they [the company] provide tools for stakeholders to find each other and exchange data: *"we try to link the different parties in the healthcare network together"*. When stakeholders make joint decisions in shaping the future digital healthcare process it is more likely that new innovations will stand.

4.8.2 Generational differences

Differences in generation, people from different backgrounds, are often a challenge when it comes to creating a shared mutual vision. The physician (4) mentions that doctors usually do not want patients to interfere with the treatment process and the data that is available, at least not before they have had a chance to look in to it themselves. He explains that, due to different generational differences, it is hard to create a mutual vision on new technologies that is supported by the different HCPs: *"There are different generations that all think in a different way, one is the generation born before 1940: everything the doctor says is true and patients rely on doctors' advice. Another generation (starting with baby boomers) are people that put the patient in a central position ('it is about me, the patient'). These patients have a circle of experts around them which they trust and ask for help with health-related questions. The next generation, young doctors and the current students is a generation that thinks in networks: the HCP gives advice, but patients have connections with many others that can also give advice"*. That last group benefits a lot from the possibility to exchange medical data and is the group that will need to lead the way in terms of setting a vision for healthcare innovation.

4.9 Privacy

Experts have different opinions on whether privacy is a direct issue for the adoption of medical app innovations. Most of them mention that it is of secondary importance, only two of the respondents mentioned privacy in their top 5 list of 'barriers to adoption'. The product manager (1) has a strong opinion on the patient perspective of privacy: *"I believe they [patients] will not actively search to find out what the quality of the underlying systems is. Instead, if it is considered useful patients will just accept it as if it is of good quality*". The Diabetes consultant (5) explains that for a lot of patient data that is stored, privacy won't be a showstopper. However, he mentions that in some rare cases it is possible that systems contain information of individuals that could harm if leaked to the public: *"There could be highly confidential data that you do not want to become publicly available, i.e., if people are beaten up, abused, or details on venereal disease. This could be used for blackmailing"*.

4.9.1 HCP resistance

There are different scenarios where privacy is mentioned as an obstacle to the adoption of new medical apps. One is the matter that HCPs are currently responsible for patients' privacy, this originates from the fact that in the Netherlands the HCP is the owner of all medical data that is stored about a patient. However, with the generation of patients that want to be in control of their own data, we see that patients start to create their own medical record. As a result, the HCP just wants to be the manager of that data, and no longer the responsible party that has to assure whether the patient data is accurate, correct and safe to use (4). A solution here could be to change the role of HCPs and let the patient themselves be the owner of their medical track record (3).

The senior policy advisor (3) and the senior advisor (9) mention that especially HCPs, when they do not like a certain technological innovation, they blame it to privacy: "*we [HCPs] cannot use this app because we are not sure whether patients data is secure"*. Privacy however, should not be a matter between the HCP and the patient, the senior advisor (9) mentions a possible solution: *"If the patient*

likes an app, and thinks it is useful, let him or her sign an 'informed consent' form, the HCP does not have to feel responsible and the privacy issue with the HCP is settled". The senior policy advisor (3) mentions that they often tell HCPs to consult with the patient, if the patient does not mind about the privacy of his or her data, there shouldn't be a problem: *"People share the craziest things on the internet, and then some data to improve one's health is not allowed. Privacy is hot topic, but it must also be discussed in an ethical sense"*. She says that the benefit of an app solution must also be taken into consideration: some apps allow a patient to stay at home and improve the quality of life because of the self-care technology.

4.9.2 Anonymity

Another important topic these days is that more and more people want to remain anonymous. Given the increase in cyber security treats in the past few years they do not want to register and leave traces of personal data online. The senior advisor at a Big 4 health insurance company (9) explains that that in the current system it is impossible to reimburse for medical apps if people want to stay anonymous, because insurers must be able to identify the patients purchase before they make the payment. The senior advisor suggests a different approach if patients want to use certain apps without sharing personal data: "*a solution could be to set a budget in the health insurance law or have the government provide a budget that patients can spend on medical app solutions free of choice*".

4.9.3 Privacy standards

The Center of Expertise for eHealth is working on the standardization of personal health records that considers safety, privacy and accessibility to systems of the general practitioner and hospitals. All apps used by HCPs must be able to adhere to these standards. This could accelerate the adoption process and assure that the privacy aspects of each individual app meet the given requirements (9). The senior policy advisor substantiates that national standards positively affects the confidence of HCP to adopt a certain app initiative: *"when an app is developed to American standards, meaning it is compliant with the FDA [the United States Food and Drug Administration], HCPs consider it safe*".

Besides the specific medical standards, there are also national and international privacy laws in place that impose standards all kinds of apps must comply with. Take the recent introduction of the European General Data Protection Regulation (GDPR) which is a regulation on privacy that primarily aims to give control to the individual over their personal data. The physician (4) explains that everyone who stores data of individuals, whether it is a HCP or an app developer, because of the GDPR they must know what data is stored and what happens with that data (i.e. who has access to the data). He mentions that hospitals still need to learn a lot and that developers can take the lead in guiding the HCPs: *"The app developers should create awareness among doctors on how to safely store and transmit data"*. He adds that there is still a lot of data transmitted via (privacy unsafe) messaging platforms like WhatsApp: *"people are not concerned whether it is safe or not"*.

5 Medical app developing organizations: guidelines for successful app adoption

To help Medical App Developing Organizations reach their full potential when they start with a new innovative solution, we created a structured overview of possible solutions to overcome adoption barriers in the Dutch healthcare market (Table 6).

The reason we use the naming of 'medical app developing organizations' instead of just developers is that most of the developing organizations that are able to create high quality apps, are not just a small team of developers, but consist of a coalition of stakeholders including HCPs and patient groups that think out and design the innovation together.

The starting point for the overview are the 9 different barrier categories as defined in the previous chapter (Table 5). For each category we have performed an analysis of all the individual barriers mentioned by the experts as elaborated in Chapter 4 and indicated the extent to which developing organizations are in control of possible solutions to overcome the barrier. Subsequently, the list has been supplemented with the barriers and solutions mentioned in the literature.

For validation purposes, we have held one single validation interview with the thesis supervisor to refine the first version of the structured overview. In this validation session we went through all the individual items. As a result of this session, we have included an extra category 'App functionality & quality requirements' to distinguish a number of app specific barriers. This was done for some of the barriers from the literature did not fit in well with the existing categorization that was compiled solely based on the results from expert interviews. The 'Source' column indicates the origin of a solution:

- Solution originate from expert interviews only (E);
- Solution originates from literature only (L);
- Solution originates from both expert interviews and literature (EL).

The extent to which medical app developing organizations are in control of a possible solution is divided into three gradations:

- The solution is fully controlled by the medical app developing organization (C);
- The solution is partially controlled by the medical app developing organization (P);
- The solution is not in control of the medical app developing organization (N).

In case a solution is partially controlled or not in control of the medical app developing organization, the column 'Required stakeholders' indicates the parties who are (partly) responsible for realizing the solution.

Table 6: Barrier-Solutions overview Medical App Developing Organizations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
1.1	Funding	Lack of business case	Misalignment between the interest of stakeholders; lack of the right vision.	A	Find enthusiastic people in the field, look for innovators that think alike, open up the conversation.	C	E	
				B	Creation of a hub to connect all stakeholders	P	E	Ministry of Health; HCP federations; Patient federations
1.2	Funding	Lack of business case	Creating a sustainable business model and finding starting capital.	A	Set a yearly 'digital health budget' in the basic insurance package for all citizens.	N	E	Ministry of Health
				B	Try out alternative reimbursement (insurer) and compensation models (Ministry of Health) for medical app use in the treatment process. Step away from fee for service to value-based healthcare.	N	EL	Health Insurer; Ministry of Health
				C	Create a coalition of HCPs and patients, if they find a particular application important, the insurer will consider including it in their offering to patients.	C	E	

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				D	Lobby for the creation of a collective group insurance policy: gives competitive advantage to the insurer; they include a product in their offering that will encourage the target group to sign up for a health insurance policy.	C	E	
				E	Have evidence-based results of the solution(s) you offer, increasing faith and trust of other stakeholders.	P	EL	HCP federations; HCP organizations
				F	Have certification in place that indicate conformity with health, safety and environmental protection standards.	C	EL	
1.3	Funding	Lack of business case	(Too) Many separate initiatives for the same disease; everyone is trying to build the next great app; this is a barrier for the collectively scaling of apps.	A	Collaboration (partnerships) among health insurers on app initiatives to opt for one and the same approach for funding and procurement of apps; i.e. not consider it competitive.	N	E	Health Insurer; Ministry of Health
				B	Have multiple HCPs join forces and realize the idea together with patient groups.	P	E	HCP federations; Patient federations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
1.4	Funding	Lack of business case	No room for HCP trials to come with evidence-based results.	A	Allow time/money for HCPs to run trials; give the opportunity to come with evidence that can motivate other people in the field.	N	E	Health Insurer; Ministry of Health; HCP organizations
1.5	Funding	Lack of business case	Investment in an app cuts in HCP turnover: receiving less patients means a decrease in billable treatments for the HCP; Pay per treatment approach.	A	Provide Healthcare organizations with a clear overview of the return on investment over time.	C	EL	
				B	Give space for doctors to experiment with new apps.	N	E	Health Insurer; Ministry of Health; HCP organizations
				C	Outcome Based Healthcare (OBH): Focus on health: the number of patients that do no longer need to visit the HCP because of improved selfcare facilities; Transition from fee-for-service to value-based care.	N	E	Health Insurer; Ministry of Health
				D	Do joint investments to develop and implement medical apps and share the savings among all parties; Social shared profits.	P	E	Health Insurer; Ministry of Health; HCP organizations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				E	Don't pay HCP per consult or app use (treatment) instead give budget to HCPs to work differently using new technologies.	N	E	Health Insurer; Ministry of Health
1.6	Funding	Unfamiliarity with available budgets	HCPs are unfamiliar with available budgets in Hospitals.	A	Clear process on what, how and where HCPs can claim budget for innovation.	P	E	HCP organizations
1.7	Funding	No hours/budget for innovation	HCPs have no hours/budget available for working on innovation; no reward.	A	Reimbursement of (extra) time to try out new app initiatives will stimulate the HCP to work on innovation	N	EL	Health Insurer; HCP organizations
				B	Provide accreditation points for healthcare innovation subjects; stimulate them in exploring medical app use cases; reward for trialing.	N	E	Ministry of Health; HCP organizations
1.8	Funding	No hours/budget for innovation	Increased cost of care for patient (pay for app use)	A	Do joint investments to develop and implement medical apps and share the savings among all parties; Social shared profits.	P	EL	Health Insurer; Ministry of Health; HCP organizations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
2.1	Healthcare professional willingness to change	Conservative culture and mindset	Contemporary culture and mindset of HCPs; resistance to immerse themselves in healthcare innovations	A	Allow more time for trials; let them test new apps without knowing the outcome upfront; without risking the possibility of not meeting targets.	N	EL	Health Insurer; HCP organizations
				B	Provide accreditation points for healthcare innovation subjects; stimulate them in exploring medical app use cases; reward for trialing.	N	E	Ministry of Health; HCP organizations
2.2	Healthcare professional willingness to change	Conservative culture and mindset	No collaborative approach of HCP that work together on the implementation of a specific app.	A	Collaboration with other HCPs to show best practices; will make it attractive for health insurers to join.	P	E	HCP federations; HCP organizations
2.3	Healthcare professional willingness to change	Change in work process	Apps being incompatible with standardized HCP work process; Initial setup takes a lot of time and interferes with HCPs work routine.	A	Allow time and space for HCP to think about how they can provide care in a different way; Allow HCP to familiarize themselves with new workflows.	N	E	HCP organizations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
2.3	Healthcare professional willingness to change	Change in work process	Apps being incompatible with standardized HCP work process; Initial setup takes a lot of time and interferes with HCPs work routine.	B	Have a responsible person in place to guide and support the implementation process; preferably someone who is active and recognized within the department.	C	E	
				C	Have a change management process in place to demonstrate that the technology really facilitates doctors and patients and that it makes their live easier.	C	E	
				D	Find both ambassadors and written evidence from medical literature; Apps must be proven for the HCP and have peer reviews. If the app meets all the requirements you can persuade people to experiment with it.	C	EL	
				E	Use of standards in HCP work processes and align app design with standard; Seamless integration.	P	EL	HCPs; HCP organizations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
2.4	Healthcare professional willingness to change	Change in work process	HCP cope with resistance from patients whom are not open for alternative treatment processes; No joy of using an app.	A	Find the right balance for contact time between patients and HCPs.	P	E	HCP organizations; Patient federations
				B	App should tempt (i.e. nudge) patients to work on their health: app must reward the patient in the care process.	C	EL	
2.5	Healthcare professional willingness to change	Lack of knowledge in the field of mHealth apps	HCP lack knowledge in the field of medical innovations (and technology) and therefore do not stimulate the use of mHealth applications.	A	Innovation on social and information level: have HCPs experience the added value of innovative solutions.	P	EL	HCP organizations
				B	HCPs need to be trained in order to make them understand new technology and products.	P	EL	HCP federations; HCP organizations
				C	Spreading evidence of the added value of medical apps; provide insights on the advantages and (financial) benefits of using new technology.	P	EL	Ministry of Health

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				D	Have a platform (by independent trusted third-party) available with an overview of the best apps that are supported by stakeholders, including a ranking and quality control system; Facilitate HCPs in finding suitable solutions for their patients; Creating a database of qualitative apps.	N	E	Ministry of Health; HCP organizations
3.1	Interoperability and integration	Stand-alone (closed) systems	Developers of medical software build stand-alone solutions; other applications are not able to use data provided from such systems; there is no communication possible between systems; no integration with legacy systems.	A	Provide open public APIs in order to communicate with [other systems]	C	E	
				B	Use of standards	C	EL	
				C	Define the interoperability standards upfront; Creation of a uniform infrastructure.	P	EL	Ministry of Health

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				D	Use of a platforms (hubs) where patients can maintain their health records (Personal Health Environments); patient in control; Platforms can connect with HIS, app is connected to platform via API.	N	E	Ministry of Health, HCP organizations
				E	HCPs can guide patients by recommending initiatives that meet interoperability standards; steer on app guidelines and platforms from recognized parties.	N	EL	HCP organizations
3.2	Interoperability and integration	Stand-alone (closed) systems	Apps often lack connection with a web-based application (web portal).	A	Integrate app within a platform or web portal, so users can access it both on their phone and on a PC.	C	L	
3.3	Interoperability and integration	Inefficiency of the current system	The complexity of exchanging data within the hospital is very high; usage of fax and scans.	A	Implement an information sharing platform within (and between) hospitals and pharmacies and replace traditional communication protocols such as fax and scans via email.	N	EL	HCP organizations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
3.4	Interoperability and integration	Dutch law	The Dutch Financial Markets Authority (AFM) restricts any firm from obtaining an unfair competitive advantage; this prevents hospital's pharmacy from gaining insight into other pharmacy's systems.	A	Restructure systems and create new rules to allow and improve collaborative sharing of data; patient subscriptions data should not be considered competitive.	N	E	Ministry of Health
4.1	Quality based app overview		People cannot find the right app for a disease in the mass of apps that are available in the app stores; There is no central place available for people to find detailed information of available apps.	A	Limit the number of high quality apps for the same disease and get a selection accepted by the larger audience.	P	E	HCP organizations
				B	Introduce laws that push app developers to comply with standards and force them to have the right certification marks for their products in place; One must make sure the product is compliant, else risk a fine.	N	E	Ministry of Health
				C	Provide/ comply with quality marks for medical apps by trusted third parties	P	EL	Ministry of Health

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				D	Have a platform (by independent trusted third-party) available with an overview of the best apps that are supported by stakeholders, including a ranking and quality control system; Facilitate HCPs in finding suitable solutions for their patients; Creating a database of qualitative apps.	P	E	HCP organizations
4.2	Quality based app overview		It is not possible to check all the available apps on appropriate content; Not possible to check 24/7 availability of the content.	A	Have a platform (by independent trusted third-party) available with an overview of the best apps that are supported by stakeholders, including a ranking and quality control system; Facilitate HCPs in finding suitable solutions for their patients; Creating a database of qualitative apps.	P	EL	HCP organizations
4.3	Quality based app overview		It is difficult for apps to reach the bigger audience.	A	Platforms; communication through different media.	P	E	Health Insurer; HCP organizations; Patient federations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				B	National campaigns and app awards.	N	E	Ministry of Health; Patient federations
				C	Hiring key opinion leaders to share their opinion on an app or platform to increase confidence among HCPs.	P	E	HCP organizations
				D	For platform developers to draw patient's attentions: involve health insurers in experiments with new products in an early stage; Health insurers are likely to include products offered through the platform in their offering to patients.	P	E	Health insurers
5.1	Co-creation		Many cumbersome apps being developed that do not meet the end-users expectations.	A	Be focused on your target group and connect with HCPs and patients in the development phase; Think like a patient.	C	EL	
				B	LEAN development approach: constantly measuring and improving the product based on end user feedback.	C	E	

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				C	App should tempt (i.e. nudge) patients to work on their health: app has to reward the patient in the care process.	C	EL	
				D	More congresses should invite patients allowing both developers and patients to collaborate on new innovations.	N	E	HCP organizations; Patient federations
				E	Participate in congresses where patients and HCPs are present; Stimulate the presence of these parties.	C	E	
5.2	Co-creation		Doctors are not familiar with available applications (being) developed.	A	Incentivize doctors to go to medical congresses by awarding them with accreditation points.	N	E	HCP organizations; HCP federations
5.3	Co-creation		Developers of medical software cannot get in touch with the right HCPs but are often redirected to some IT department.	A	Incentivize doctors to go to medical congresses by awarding them with accreditation points.	N	E	HCP organizations; HCP federations
				B	Participate in congresses where HCPs are present; Stimulate the presence of these parties.	C	E	

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
5.4	Co-creation		Acknowledgement by health insurers	A	Involve the health insurer in the development phase, discuss content and offering approach; if you meet the insurers requirements and the insurer is already familiar with your product it is more likely that they want to include the product in their offering to patients.	P	E	Health insurers
6.1	Digital Literacy		People with poor digital literacy lack knowledge on the possibilities of mHealth; There is a lack of information provisioning.	A	People need to be guided and require some practice before they understand how to use an app and associated benefits.	P	EL	HCPs
				B	Social innovation: think about how to introduce new innovations in healthcare within different socioeconomic groups.	P	EL	Ministry of Health; HCP organizations; HCP federations; Patient federations
				C	Provide training on relevant subjects.	P	EL	HCP organizations; Patient federations; HCP federations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
6.2	Digital Literacy		Many patients are not used to a smartphone yet; Difficulties in using the technology.	A	People need to be guided (by developer and HCPs) and require some practice before they understand how to use an app and associated benefits.	P	E	HCPs
				B	Take design principles into account with respect to learning and cognitive disabilities.	C	L	
6.3	Digital Literacy		Lack of support during the implementation phase: technology developed by young men for old woman.	A	Co-creation; Collaborative approach of guiding and supporting the users through the process, instead of just handing over a new solution.	P	E	HCPs; Patient federations
				B	Provide training on relevant subjects	P	EL	HCP organizations
7.1	Evidence		Lack of good figure on the real added value (and risks) of implementing a medical app; Only a few studies available that clearly show the effect on number of incidents, hospital admissions and communication improvements.	A	Faster validating procedures than randomized controlled trials are necessary to demonstrate the of a product in a short timeframe.	P	E	Ministry of Health

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				B	More research on the added value of apps, economically, financially, but also in terms of quality and health.	P	EL	Ministry of Health
				C	Risk-benefit assessment (trusted third party): what are the risks of using mobile devices or a specific app in a hospital.	P	L	HCP organizations; HCP federations; Ministry of Health
7.2	Evidence		User retention is often poor.	A	More research on how to increase the 'sustainable use' of app solutions and added value for consumers.	P	E	Ministry of Health
				B	Directives on an organizational level; Set goals and quotas to stimulate app use: e.g. reduce in-hospital treatments with 20% by using self-care apps for patients.	N	L	Ministry of Health; HCP organizations
7.3	Evidence		App developers often cannot afford the cost of both launching a product and scientifically proof its added value.	A	Faster validating procedures than randomized controlled trials are necessary to demonstrate the of a product in a short timeframe.	P	E	Ministry of Health

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
7.4	Evidence		Doctors find it hard to rely on data provided by medical apps and devices; Dealing with professional security and clinical uncertainty when app is used in treatment.	A	Creation of certification marks by trusted third parties.	N	EL	Ministry of Health
				B	Have certification in place that indicate conformity with health, safety and environmental protection standards.	C	EL	
				C	Have statement(s) of app being compliant from trusted third party (audit).	C	L	
				D	Monitoring and control by supervisory body on app compliance with regulation.	N	L	Ministry of Health
8.1	Vision on healthcare innovation		Innovations are seen as separately stacked elements: add mHealth as extra to the current process instead of changing the actual treatment approach.	A	The existing care process should be the starting point for digital transformations: stakeholders design alternative approaches and discuss on how to implement new treatment offerings for patients.	P	E	HCPs; Patient federations; HCP organizations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				B	Have a dialogue on both regional and national level about healthcare innovation, to explore how we can continue to provide care in the future with the help of new technologies; Communication between parties in the healthcare sector (HCPs, insurers, developers, governmental organizations).	P	EL	Ministry of Health; HCP organizations; HCP federations; Patient federations; Health insurers
8.2	Vision on healthcare innovation		There are many separate HCP organizations each with its own specific systems and processes, which is a challenge for developers who want to implement solutions with a uniform infrastructure.	A	Push all the relevant stakeholders of your product in the right directions.	C	E	
				B	HCPs can facilitate by integrating standards with other HCPs; Create a seamlessly functioning healthcare network using a single standard for systems and processes.	P	E	HCPs; HCP organizations; Ministry of Health

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
8.3	Vision on healthcare innovation		Differences in generation, people from different backgrounds, are a challenge in creating a shared mutual vision.	A	The new generation of doctors and students that think in networks should create the vision for healthcare innovation; Developing organizations can push/stimulate.	P	E	HCPs; HCP organizations
9.1	Privacy		Apps can contain highly confidential data that HCP/Patients do not want to become publicly available.	A	National standards for personal health records considering safety, privacy and accessibility to systems of HCPs.	N	EL	Ministry of Health; HCP organizations
				B	Let patient sign an 'informed consent' form if they like to use an app so the HCP does not have to feel responsible.	N	E	HCPs; Patient federations
				C	Have certification in place that indicate conformity with privacy standards.	C	EL	
9.2	Privacy		In the Dutch system HCPs are currently responsible for patients' privacy; HCP is owner of all medical data stored about the patient.	A	Change the role of the HCP and let the patients themselves be the owner of their medical track record; allow patients to create their own medical record.	N	E	Ministry of Health; HCP federations

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
				B	(Change in) National standards for personal health records considering safety, privacy and accessibility to systems of HCPs.	N	E	Ministry of Health
9.3	Privacy		HCPs that do not like a technological innovation blame it to privacy.	A	Let patient sign an 'informed consent' form if they like to use an app so the HCP does not have to feel responsible.	N	E	HCPs; Patient federations
				B	(Change in) National standards for personal health records considering safety, privacy and accessibility to systems of HCPs.	N	E	Ministry of Health
9.4	Privacy		People want to remain anonymous and don't like to share personal information when using an app.	A	Set a budget in the health insurance law or have the government provide a budget that patients can spend on medical app solutions free of choice; Instead of having to share all your personal information before you get a reimbursement from the insurer.	N	E	Ministry of Health

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
9.5	Privacy		Ignorance of international privacy laws that medical app developers and app users (HCPs and patients) must comply with; e.g. GDPR.	A	Take international privacy laws in consideration when you start developing an app.	C	E	
				B	Developers can take the lead in guiding the HCPs, create awareness among doctors on how to safely store and transmit data.	C	E	
10.1	App functionality & quality requirements		Accessibility: requirement to login with a username, password and extra verification technique(s). Can be time consuming and difficult to understand.	A	Make use of more convenient online user verification technologies (that become) available.	C	E	
10.2	App functionality & quality requirements		Time consuming: often apps are too complicated for end users.	A	App must be fool proof, test with dummies (different end-user groups).	C	E	
				B	Data entry automation; e.g. direct communication with the glucometer; continuous monitoring.	C	L	

#	Barrier category	(Sub Category)	Individual barrier	#	Solution	Control	Source	Required stakeholders
10.2	App functionality & quality requirements		Limited features: lack of individually important functions; Unnecessary functions (lack of customization).	A	Do (or use existing) research on different types of users and use as input for app development (user centered design approach)	C	EL	
				B	Allow users to customize app functions (modules) to their needs (individual tailoring)	C	EL	
				C	Be focused on your target group and connect with HCPs and patients in the development phase; Think like a patient.	C	E	

The extent to which a medical app developing organization is in control of a possible solution is summarized in Table 7. We can see from the totals that there is a fairly even distribution among the three gradations. However, the extent to which developing organizations can (partly) control the solutions for the above list of barriers is more than two-thirds. In other words, the impact they can make to overcome challenges in medical app adoption is relatively high. For the solutions that are partially controlled, the app developing organizations can often stimulate and steer the other required stakeholders to increase the chance for success of solving a specific challenge. The solutions that are not in control of the medical app developing organizations refer to specific actions by other stakeholders that are required to overcome the barrier. In the beneath chapters we provide a short summary of the actions medical app developing companies can take to overcome challenges within each category.

Table 7: Extent of control over solutions per category

Barrier category	Solutions fully controlled	Solutions partially controlled	Solutions not in control
Funding	5	6	9
HCP willingness to change	4	6	4
Interoperability and integration	3	1	4
Quality-based app overview	0	7	2
Co-creation	5	1	3
Digital literacy	1	6	0
Evidence	2	5	3
Vision on healthcare innovation	1	4	0
Privacy	3	0	7
App functionality & quality requirements	6	0	0
Totals	**30**	**36**	**32**

5.1 Funding

As seen in chapter 3.2 and chapter 4, the majority of barriers mentioned by experts and in literature are financially related. Although only 5 out of 20 solutions are in direct control of the medical app developing organizations, they have the capacity to nudge other stakeholders and reveal insights on the added value of healthcare innovation. Actions that developing companies can take to improve the business case are mainly focused on bringing the various stakeholders together. They should create an ecosystem where enthusiastic people in the field are brought together. Team up and create a coalition of HCPs and patients that support the medical app solution being developed. Through such a collaboration, it can be easier to run trials and to obtain figures on both the improved health outcomes and return on investment over time. Another solution that requires action from the developing party is the conformity with different standards. This should preferably be considered in the initial phase before the actual development starts. If one develops an app solution that qualifies for the required certifications it is more likely that the product will seamlessly integrate within the market. In retrospect, it is always more work to redesign processes in such way that the outcome is compliant and accepted by the market. By creating a more complete picture on the viability of the app solution through a business case supported by multiple stakeholders, one opens the door for health insurers to include the product in the reimbursement offering to patients, reaching the bigger audience. An extra incentive to convince insurers is when app developing companies already target collective groups of potential users that are likely to benefit from the solution. That way an insurer can offer a collective group insurance policy to the target group and gain some competitive advantage relative to other insurers that are not able to provide the solution in their offering.

5.2 HCP willingness to change

The second most mentioned barriers are related to the individual experience and motivation of healthcare professionals to engage in experiments with medical app initiatives. Solutions for barriers that can be controlled by medical app developing organizations are mainly related to the difficulties HCPs have with the required change in existing work processes. As can be seen in Chapter 4.2, many HCPs explain that they struggle with the implementation of new app initiatives because often the apps are incompatible with standardized hospital processes and interfere with the current work routine. The medical app developing party can take action by having a person at the care facility that is responsible and available to guide the implementation process explained one of the experts in 4.2.2. When a small implementation team is able to demonstrate that the technology really facilitates the doctors and patients it is more likely that others will follow trialing. This will result in a snowball effect: once the medical app solutions find traction within a small group of users, the collection of evidence starts which again enables other HCPs to experiment with the solution. Ambassadors can spread the word and explain on the treatment and health benefits. Another action that developing organizations have to take into consideration is that apps should tempt patients to work on their health. Often HCPs experience resistance from patience whom are not interested in using the app as alternative to the standard treatment methods. If the app rewards patients in the care process, for example using gamification techniques, it is expected that the patient will have more joy using the app solution.

5.3 Interoperability and integration

Actions named by experts in chapter 4.3.1 from the integration perspective that can help to overcome some of the adoption barriers in this area seem quite straightforward: build open systems that provide open (public) application programming interfaces (APIs) to allow communication with other systems and make use of interoperability standards. The reality however is more complex as many different HCP organizations use different standards and (legacy) HCP Information Systems. Therefore, the priority is to create a uniform infrastructure for the healthcare network on a regional and national level. App developing organizations can contribute by not just developing something towards a single standard but take part in the conversation with HCP organizations and the ministry of Health focused on creating future proof healthcare information technology standards.

5.4 Quality based app overview

Within the ‘quality-based app overview’ category there are no barriers mentioned by either literature or experts which medical app developing organizations can tackle on their own. Nevertheless, there are a few actions they can take to contribute to a solution. One solution that is mentioned multiple times in chapter 4.4 is the use of platforms with an overview of the best apps that are supported by HCPs, creating a database of high quality apps. Medical app developing organizations can benefit from these platforms reaching the bigger audience, therefore it is important to prepare for possible requirements to be listed on the platform. Again, it is very likely that these platforms will integrate with national standards or app quality marks by trusted third parties. As a developing organization you can have a head start relative to other similar apps if you stay up to date with the developments and comply to these standards. Another solution that is mentioned for apps to reach the bigger audience is to increase the confidence among HCPs through hiring key opinion leaders. If they share their opinion and success stories on your app in the field it likely that other people get enthusiastic and start to experiment as well.

5.5 Co-creation

Co-creation, as defined in Chapter 4.5 being "app developing companies working together with relevant patients and HCPs in order to synergistically create useful mHealth apps" is a category where the medical app developing organizations are in control of the majority of solutions to overcome the adoption challenges. One expert mentions that apps have to be of extremely high quality, if your app content doesn't meet the end-user's expectations you are out of play. In other words, it is important that the developing party is connected with HCPs and patients in the development phase, following a LEAN development approach where you constantly measure and improve the product based on end user feedback. A solution mentioned earlier in 5.2 is that apps really have to nudge patients to work on their health by rewarding the patient in the care process, a LEAN development approach can help incorporating such requirements. If people don't experience long term added value they are not likely to continue using the app. A barrier however, is that often app developing organization find it hard to get in touch with the right HCPs. This could be overcome by attending congresses where HCPs are present or by stimulating the presence of such parties at healthcare innovation conferences. Furthermore, it is mentioned that it can be useful to connect with health insurers in an early stage to discuss their requirements to include the product in the offering to patients.

5.6 Digital literacy

The barriers related to digital literacy are related to end-users that have no clue of how to cope with new digital technologies or people that just require a lot more time to comprehend its functionality. One thing is that these people need to be guided step by step when you introduce them to new innovations. However, on the other hand the developers can take design principles in mind with respect to learning and cognitive disabilities, e.g. include the option to use the app in a 'beginner' mode. This way rookies can use the basic functionality and more experienced users can use the advanced options and customize the app to their own liking.

5.7 Evidence

Without having any proof of the improved care outcomes and financial return on investment of implementing your app in the treatment offering, it is unlikely that people will support the solution. Direct actions that medical app developing organizations can take are the obtaining of certification and proof that your app is compliant to different standards in the market. If a trusted third party audits your app and states that you meet with the highest standards the other parties will have more confidence implementing the app. When your app complies with all the standards then you can push HCPs to use the app and start generating evidence on the economical and health benefits: the snowball effect described earlier in 5.2. Alternative ways for validating medical app solutions are to be investigated, app developing companies should pay close attention to new trialing initiatives when they come available in the market.

5.8 Vision on healthcare innovation

This category is focused towards creating a mutual vision on healthcare strategy. Communication between HCPs, insurers, the government and developers is the key to this challenge: having a dialogue on regional and national level to explore how we can continue to provide care in the future with the help of new technologies. Medical app developing organizations can again push the other stakeholders in the right direction: showcase what technology of the future is capable of and encourage them to experiment with new innovations.

5.9 Privacy

The privacy challenge, how to cope with confidential patient data and making sure you comply to all the laws and regulations can be a big burden for medical app developing organizations. Notwithstanding it is import for them to have the right certification in place that indicate conformity with these standards. It can be advantageous to take international privacy laws into consideration prior to the development phase, many projects fail to find traction because they did not incorporate privacy requirements in their product design. Another solution to solve the privacy issue in general, is that developing organizations can take the lead in guiding HCPs, creating awareness among doctors how to safely store and submit data. Often mentioned by the experts is that doctors are not aware of what is safe or not, this 'black-box' of regulations results in HCPs being reluctant in using new medical apps. When they are accompanied by experts on this subject it is more likely that they also want to invest their time in exploring app possibilities.

5.10 App functionality & quality requirements

The last category contains the barriers that are directly related to app specifics, as a logical consequence the app developing organizations have control over all the possible solutions that are mentioned to overcome these challenges. These are actions that should be considered during the development phase of the medical app. One of the issues is that end-users often find using the app a too time-consuming task, many apps are just too complicated in their use. Action medical app developing companies can take, to avoid that they put time and effort in building the next great app that is never used, is again a LEAN and user centered development approach. The development requires continuous cycles of testing with end users, focusing on different end-user groups. Using research on the different types of users to improve app design. Ease of use is one of the most important requirements to increase user retention. Technologies such as fast and simple user verification (instead of login with username and password) and data entry automation (patient measurements being transmitted from device to device) are among the mentioned solutions. Another solution already mentioned in the previous chapters is to allow the end user to customize app functionality to their needs. This could also mean that functionality is split up into different modules that can be switched on and off, by doing so the patient only has to deal with functionality that is important to them.

6 Conclusion and discussion

This chapter includes the conclusion for this research followed by a discussion on the limitations and possible future work that can result from this thesis. For the research questions as provided in Chapter 1.1.1, the sub-questions are answered first followed with a conclusion of the main research question.

6.1 Conclusion per sub-question

The starting point for this research was the literature study on medical app adoption barriers and the Dutch Healthcare structure. The sources that we found in the literature study were sufficient to answer the first two sub-questions. The results from the literature study created the basis for the expert interviewing and main literature findings were presented to the experts. The expert interviews complemented the findings from the literature and provided the input to answer sub-question three and four. Sub-question five was answered by analyzing the combination of literature and interviewing results from the perspective of medical app developing organizations. The last sub-question six was answered based on expert recommendations and a validation interview. In the beneath sub-chapters we provide a conclusion for every sub-question.

6.1.1 Sub-question one

The purpose of the first question was to find factors in existing literature that could improve the adoption of medical apps. The question was drafted as:

"What factors are important for successful adoption of medical apps in the market according to literature?"

Through the literature study we created an overview of the different barriers to medical app adoption which can be found in Table 2 on page 20. The classification resulted in six main categories of adoption barriers, which are:

- Perceived usefulness and ease of use;
- Dependability and evidence;
- Security, privacy and regulations;
- Integration and interoperability;
- Individual and experience;
- Financial.

The individual barriers pinpoint the factors that require attention. If available, we included suggestions for solutions to overcome these barriers. A summary of the results can be found in Chapter 3.2. Table 2 together with the corresponding explanation and possible solutions give an answer to sub-question one.

6.1.2 Sub-question two

The second sub-question was also answered through literature, especially studies focused on the Dutch healthcare system. The question was as follows:

"Who are the stakeholders involved in the Dutch healthcare sector?"

Through the literature and document study in Chapter 3.3, we were able to create an overview of the Dutch healthcare landscape and the stakeholders that are responsible within as shown in Figure 6 on page 25. In Figure 7 (page 25) we extended the schema with the positioning of mHealth technology, representing the medical app developing organizations. In total we classified five main stakeholders groups being:

- The Government (Ministry of Health) including the Dutch Healthcare authority (NZa);
- Health insurers;
- Healthcare professionals;
- Patients;
- Mobile app developing organizations.

Figure 7 together with the explanation in Chapter 3.3 provide the answer to sub-question two.

6.1.3 Sub-question three and four

The first two sub-questions where combined and used as input for sub-question three. This question was posed as:

"What factors are important for successful adoption of medical apps that healthcare stakeholders consider?"

Sub-question one and three were the basis for sub-question four. The question was drafted as:

"How do the factors for successful medical app adoption from both literature and the different experts relate to each other?"

The results from sub-questions one and two contributed to the creation of the expert interviewing protocol and guided the elicitation process of medical app adoption factors by the experts. The adoption barriers from literature were presented to the experts after which they were asked to create a prioritized list of their top five barriers. The combination of findings mentioned by the experts and those from literature resulted in a final classification of important adoption barriers, resulting in a total of nine categories, which are:

- Funding;
- HCP willingness to change;
- Interoperability and integration;
- Digital literacy;
- Quality based app overview;
- Co-creation;
- Vision on healthcare innovation;
- Evidence;
- Privacy.

Table 5 on page 28 provides an overview of the barrier categories as listed above in relation to the interviewed experts and shows the expert priority score for each category. In Chapter 4 we provided a thorough explanation of the different categories with all the individual barriers that were mentioned by the experts. The explanation incudes possible solutions from experts and literature for each barrier and together with the prioritization provides the answer to sub-question three and four.

6.1.4 Sub-question five

Sub-question four was the basis for sub-question five which is worded as follows:

"How to construct an instrument that supports medical app developing organizations in such a way that more apps find adoption in the market? "

Through extensive analysis of the different barriers and corresponding solutions from Chapter 4 we have come up with a structured overview that lists solutions to overcome the individual adoption barriers from a medical app developing organization perspective (Table 6, p46). From the structured

overview one can see the amount of control that a medical app developing organization has in realizing one of the solutions. Chapter 5 provides an explanation on the possible actions these companies can take to overcome these obstacles and increase the chance for an app to find adoption. The structured overview in Table 6 in combination with the explanation in Chapter 5 provide clear guidelines for medical app developing organizations on possibilities to increase app adoption and is deliverable of and answer to sub-question five.

6.1.5 Sub-question six

The deliverable of sub-question five is input for the final sub-question, which was posed as:

"What is an appropriate way to validate the proposed instrument?"

The first version of the structured overview in Table 6 was validated through an interviewing session with the thesis supervisor. As a result, we refined the list as explained in Chapter 5, which is the deliverable of sub-question six.

The suggestion from the interviewed experts was to organize a focus group where the different experts can participate and have a discussion on the importance and solubility of the proposed solutions. However due to the boundaries of this thesis project, constraints in time and availability of experts we have not been able to schedule such a session. However, for future work this would be a very valuable addition to the current deliverable and increases its validity.

6.2 Conclusion main research question

The main research question for this thesis research is as follows:

"How can the adoption of medical apps for patients with chronic conditions in the Dutch healthcare sector be improved?"

The main research question is answered by the sub-questions that are discussed in the previous section. Both the literature and interview results were focused on finding factors to increase the chances for adoption of self-care apps for patients with chronic diseases. An extensive list of possible solutions to overcome adoption challenges in the Dutch healthcare structure is discussed and described in this research. Main findings are that the collaboration between the different stakeholders is key in the process. Co-creation (Chapter 4.5) is mentioned as one of the most important solutions: teaming up and working together on the realization of a medical app innovation. By doing so one increases the ability to overcome the other adoption barriers among which the creation of a sustainable business case that is supported by multiple stakeholders (Chapter 4.1.1). Another frequently mentioned obstacle was the resistance among healthcare professional that are not yet willing to invest in medical app innovations (Chapter 4.2). Issues are on the one side a lack of digital health literacy, but on the other side often medical app solutions interfere with the HCP work process and do not integrate well with existing HCP information systems. Medical app developing organizations can nudge HCPs to trial with new app initiatives and they should guide the HCP through the implementation process. However, without clear regulation and a uniform infrastructure it will remain very hard to create apps that find adoption among the bigger audience. The Ministry of Health could take the lead in the creation of such standards (Chapter 4.3.5). The deliverable (Table 6) that is proposed in this thesis contains an overview of possible solutions to adoption barriers and the responsible stakeholders that are required to take action on that solution. Medical app developing organizations can use the overview as a set of guidelines that can be taken into account when one wants to start with the development of a medical app idea for the Dutch healthcare market.

6.3 Future work & Limitations

6.3.1 Limitations

During the research process several limitations for this thesis project were observed. First of all, the research relies heavily on the Dutch healthcare market. A lot of topics and research questions regarding mHealth need more coverage to realize its full potential, but unfortunately due to limited time and resources, in this thesis we only focused on adoption barriers in the Dutch healthcare ecosystem. As a result, most of the findings from expert interviews, which are all active within the Dutch healthcare system, provide solutions that are merely applicable to medical app developing organizations active in the Dutch market. Furthermore, the interviews were held with different stakeholder groups in the Dutch healthcare market. Given the relatively small number of interviews for some stakeholder groups we cannot generalize all the findings for that specific stakeholder group.

Another limitation is the single validation interview that was conducted. It has not been possible to double check with app developing organizations whether the guidelines are indeed of significant value on the app adoption process. The feedback from the experts that were interviewed suggested for a validation of the deliverable (Table 6) through a case study or focus groups. However, there was no time to arrange such sessions at short notice.

6.3.2 Future work

As mentioned there is a lot of research possible in the field of healthcare innovation. Firstly, the results of this research should be discussed through focus groups and tested in multiple case studies with medical app developing organizations. Secondly, results could be extended by interviewing more experts per stakeholder group in order to get a more balanced overview of the different stakeholder interests. In our research we have mainly interviewed people that are familiar in the field, or that are active ambassadors of healthcare innovation. The ‘normal’ person might be able to complement the findings from a different perspective.

Furthermore, it did be interesting to widen the ecosystem and make a comparison to the medical app offering in other countries to see whether an approach for app adoption and implementation on international level would be feasible.

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8 Appendices

8.1 Appendix 1: Summary of papers addressed in literature research

Table 8: Summary of papers addressed in literature research

#	Study	Country	Methodology/ Study design	Data collection	Participants/ sample size or Target group	Aims	Intervention
1	Scheibe, 2015	Germany	Qualitative	Interviews, observation	Patients/32	Investigation of the factors that influence the acceptance of diabetes apps among patients aged 50 or older.	Interview session to obtain subjective perspective of elderly diabetes patients, followed by the testing of two existing diabetes apps on a tablet to reveal obstacles in (first) use.
2	Gagnon, 2015	Multiple	SLR	PubMed, EMBASE, CINAHL, PsychInfo	Healthcare Professionals	Synthesize the scientific literature on the factors that could facilitate or limit healthcare provider utilization of m-health in their work.	Included studies if they reported the perceptions of healthcare professionals regarding barriers and facilitators to m-health utilization. Content analysis using a validated extraction grid with pre-established categorization of barriers and facilitators.

#	Study	Country	Methodology/ Study design	Data collection	Participants/ sample size or Target group	Aims	Intervention
3	Wu, 2011	Taiwan	Quantitative	Survey	Healthcare Professionals/140	Survey to examine the acceptance of healthcare professionals in hospitals.	Send out questionnaires to 80 randomly selected hospitals, 10 per hospital, response 140/800. Questions categories: Perceived usefulness, perceived ease of use, attitude, perceived behavior control, subjective norm, Behavioral intention, personal innovativeness in IT, perceived service availability.
4	El-Gayar, 2013	Multiple	SLR	PubMed, Web of Science, IEEE, ACM	Patients	SLR to determine whether diabetes applications have been helping patients with type 1 or type 2 diabetes self-manage their condition and to identify issues necessary for large-scale adoption of such interventions.	The review included all applications (available on the Apple App Store) supporting any diabetes self-management task where the patient is the primary actor.
5	Banchs, 2014	USA	Quantitative	Survey	Patients/118	Investigation the limited use of health applications by cardiology clinic patients.	Patients from three outpatient cardiology clinics were surveyed regarding their use and attitudes towards mobile technology for monitoring their conditions.

#	Study	Country	Methodology/ Study design	Data collection	Participants/ sample size or Target group	Aims	Intervention
6	Banner, 2013	Multiple, UK (81%)	Quantitative	Survey	Patients/250	The aim was to determine the qualities people seek in their health apps, learn which of these qualities is the most important, and find out how needs vary among different patients and people.	Patients provided feedback on whether the five statements (see findings) were important to them. Groups were asked to point out the app attribute most important to them.
7	Beatty, 2013	Multiple	SLR	PubMed	Patients	To examine the existing literature on the use of mobile technology for cardiac rehabilitation and propose a framework for developing and evaluating mobile applications for cardiac rehabilitation.	SLR on studies that involved mobile phone interventions for cardiac rehabilitation for patients with IHD
8	Boulos, 2014	Multiple	Quantitative	Survey	Multiple	Examine the state of the art in mobile clinical and health related apps.	N/A
9	Buijink, 2012	Netherlands	Quantitative	N/A	N/A	Examine the current and future state of app quality and safety, and a medical app regulation strategy.	Proposes several strategies to enhance the development of evidence-based medical apps while retaining their open nature.

#	Study	Country	Methodology/ Study design	Data collection	Participants/ sample size or Target group	Aims	Intervention
10	Coöperatie Zelfzorg Ondersteund, 2014	Netherlands	N/A	N/A	Patients, Health care professional	Large scale implementation (and integration) of self-care, by providing an assessment framework of the basic requirements (functional and technical) for self-care applications and platforms.	Collaborative approach of multiple stakeholders in the Dutch healthcare sector to come up with a set of assessment criteria that self-care applications should comply with.
11	Dehling, 2015	Multiple	Quantitative	Survey	Patients	The objective of this study was to establish an overview of mHealth apps offered on iOS and Android with a special focus on potential damage to users through information security and privacy infringements.	They assessed apps available in English and if these were offered in the categories “Medical” and “Health & Fitness” in the iOS and Android App Stores. Information security and privacy implications were assessed based on health specificity of information available to apps, potential damage through information leaks, potential damage through information manipulation, potential damage through information loss, and potential value of information to third parties.

#	Study	Country	Methodology/ Study design	Data collection	Participants/ sample size or Target group	Aims	Intervention
12	Dehzad, 2014	Netherlands	Quantitative, Qualitative	Literature study, Questionnaire, Interviews	Multiple	Find barriers to mHealth adoption.	Find existing barriers in literature study, and next present these to Key Opinion Leaders within the broader context of mHealth to quantify importance.
13	Demidowich, 2012	USA	Quantitative	Survey	Patients	Evaluate the available diabetes apps for Android smartphones.	Review of free and paid apps in April 2011, by searching the Android market for apps which could track self-monitoring of blood glucose (SMBG), diabetes medications, calculate prandial insulin dosages. Evaluated six features per app, in total 42 unique apps included.

#	Study	Country	Methodology/ Study design	Data collection	Participants/ sample size or Target group	Aims	Intervention
14	Forman, 2014	USA	Quantitative	Survey	Patients	Assess the feasibility and utility of a mobile smartphone application for CR, Heart Coach (HC), as part of standard care.	Twenty-six patients enrolled in CR installed HC. Over the next 30 days, they were prompted by HC to complete a daily "task list" that included medications, walking, education (text and videos), and surveys. Cardiac rehabilitation providers monitored each patient's progress through a HC-based Web dashboard and sent them personalized feedback and support. Completion of the tasks and feedback (qualitative and quantitative) from patients and clinicians were tracked.
15	Gallagher, 2015	UK	Qualitative	N/A	Multiple	Provide an overview of the current state of medical applications and makes suggestions on how to improve the app adoption.	N/A

#	Study	Country	Methodology/ Study design	Data collection	Participants/ sample size or Target group	Aims	Intervention
16	Casey, 2014	Ireland	Quantitative, Qualitative	App (smartphone sensors), interviews	Patients/90	The aim of this study is to evaluate the effectiveness of a smartphone application as an intervention to promote physical activity in primary care.	90 app users, 12 were interviewed afterwards
17	Wyke, 2013	UK	N/A	N/A	N/A	Informative article on the future of healt apps and their prescription to patients.	N/A
18	Katz, 2015	UK	Quantitative, Qualitative	interviews	Patients/27	Evaluate the current use and perceived benefits of Diabetes apps by diabetics.	Age range: 3-61 years, mean 31.3 years (SD ±13.1). Diabetes duration: range 1-54 years, mean 15.67 (SD± 12.26). Gender: 37% female.
19	Kaufman, 2014	USA	SLR	N/A	Patient	Overview of diabetes interventions to extract information on the efficacy of health app usage.	Multiple
20	Kumar, 2013	USA	Qualitative	Workshop	Patients	Research and list ways of intervention to generate evidence to assess when, where, and for whom mHealth devices, apps, and systems are efficacious.	Multiple
21	Janssen, 2013	Netherlands	N/A	N/A	Patients	To provide insight on innovation paths for new mHealth solutions in the Dutch healthcare structure.	Overview of all the different stakeholders, their main interests, and how to convince them to accept your care product.

#	Study	Country	Methodology/ Study design	Data collection	Participants/ sample size or Target group	Aims	Intervention
							Followed by different paths of bringing your product to the market.
22	Nictiz, 2016	Netherlands	Quantitative	Questionnaire	Patients, Health care professional	Provide an overview of the current state of the Dutch eHealth developments over the past year. Including the conditions for successful deployment of eHealth innovations, the degree of availability and effective use of the various application areas, and recommendations for the government and healthcare practice.	Extensive survey among representative groups of healthcare professionals and healthcare users in the period of 2015 (spring) - 2016 (spring).
23	RIVM, 2013	Netherlands	N/A	N/A	N/A	Literature study commissioned by the Dutch healthcare inspection (IGZ) to provide insights on the possible eHealth risks for healthcare organizations, professionals and patients.	N/A
24	Schoffman, 2013	USA	Quantitative	Appstore	57 apps	Investigate the available apps for the prevention and treatment of pediatric obesity for children under 18 years old.	Analysis of the content of 57 apps (iOS) for pediatric weight loss, healthy eating and physical activity.

8.2 Appendix 2: Interview protocol

Medical app adoption in the Dutch healthcare sector

Welcome

Thank you for participating in my thesis research. The timeframe for this interview session is 1 hour. The purpose is to discuss the relatively slow adoption rate of medical apps for *chronic diseases* in the Dutch healthcare market.

We will start pinpointing the most important barriers to adoption using a schematic overview of the different stakeholders in the Dutch healthcare sector. If something is not clear during the interview, feel free to ask.

Objective

The primary objective of this interview is to investigate the interests of [healthcare professionals] [patients] [health insurers] [other stakeholder…] in mobile medical apps for chronic diseases, what the main barriers/solutions are for successful medical app adoption and how they can be supported in the app adoption process.

Checklist

- Approval for recording the session

Interview

A) Introduction [5 mins]

Could you provide me with a short introduction about yourself?

INTRO1. What is your name?
INTRO2. Where are you from?
INTRO3. How did you get involved in the medical (apps) domain?
INTRO4. What is your day to day job now?
INTRO5. Do you use or work with medical apps, to what extend?

B) Exploratory [10mins]

Stakeholder specific process

Q1. Tell me about the things I might want to know… *[5 mins]*

Questions for Healthcare professional

a. When we want to get a medical app for chronic diseases implemented and accepted among the different stakeholders in the Dutch healthcare sector;
b. When somebody wants to start using an app for his or her disease;
c. When you want to prescribe an app to patients.

Questions for health insurer

a. When we want to get a medical app for chronic diseases implemented and accepted among the different stakeholders in the Dutch healthcare sector;
b. When a patient wants to apply for reimbursement of an app.

Questions for patient / patient association

a. When somebody wants to start using an app for his or her disease.

Questions for Ministry of Health, VWS

a. When we want to get a medical app for chronic diseases implemented and accepted among the different stakeholders in the Dutch healthcare sector.

Dutch healthcare landscape

Q2. Do you think this schematic overview of the Dutch healthcare landscape is complete or are we missing some important stakeholder or relation? (Appendix I) *[5 mins]*

C) Adoption barriers and solutions

Q3. When you think of the barriers that hinder medical app adoption, which do you think are the most important and could you locate them in this overview? *[10 mins]*

a. Mark the weak links on the drawing.

Q4. Could you propose one or more solutions for the barriers you mentioned? *[5 mins]*

a. Limit to top 5 solutions.
b. Check if different perspectives are met, related to:
    i. Mobile app characteristics;
    ii. Technology (in general, infrastructure)
    iii. Individual (end user): Knowledge, Education, Attitude, and Socio-demographic characteristics;

iv. Internal organizational environment: Organizational factors, Resources availability;
v. External organizational environment: Financing, Healthcare policies and socio-political context.

c. Check if it is clear what stakeholder(s) is (are) mainly responsible for providing the solutions mentioned.

Q5. Consider the following list of barriers / solutions (Appendix III). *[5 mins]*

a. Do you recognize these?
b. Do you agree?
   i. Or are some already solved or not applicable
   ii. And do you think these solutions are useful
c. Can you think of (other) suitable solutions for the barriers?
d. Check if it is clear what stakeholder(s) is (are) mainly responsible for providing the solutions mentioned.

Q6. Now we have extended the list of solutions that should be implemented, could you prioritize the proposed solutions? *[5 mins]*

a. 100$ test, prioritization by weighing against each other. (Appendix II)

D) Interview – Future, what can we expect [5mins]

Medical app prospects

Q7. Is compliance when using medical apps, a significant problem for you?

Q8. Do you think certification would help in the adoption process of a medical app?

Q9. Do you think medical apps will be the future of healthcare?

a. Is it pertinent to invest in medial app adoption?
b. What are the next steps for medical apps / mHealth?

Information

- Thank you for your time.
- Explain next steps in research.
- Would you like to be informed about the results from this study?
  - Email:

Interview appendix I: Overview of all stakeholders in the Dutch healthcare sector

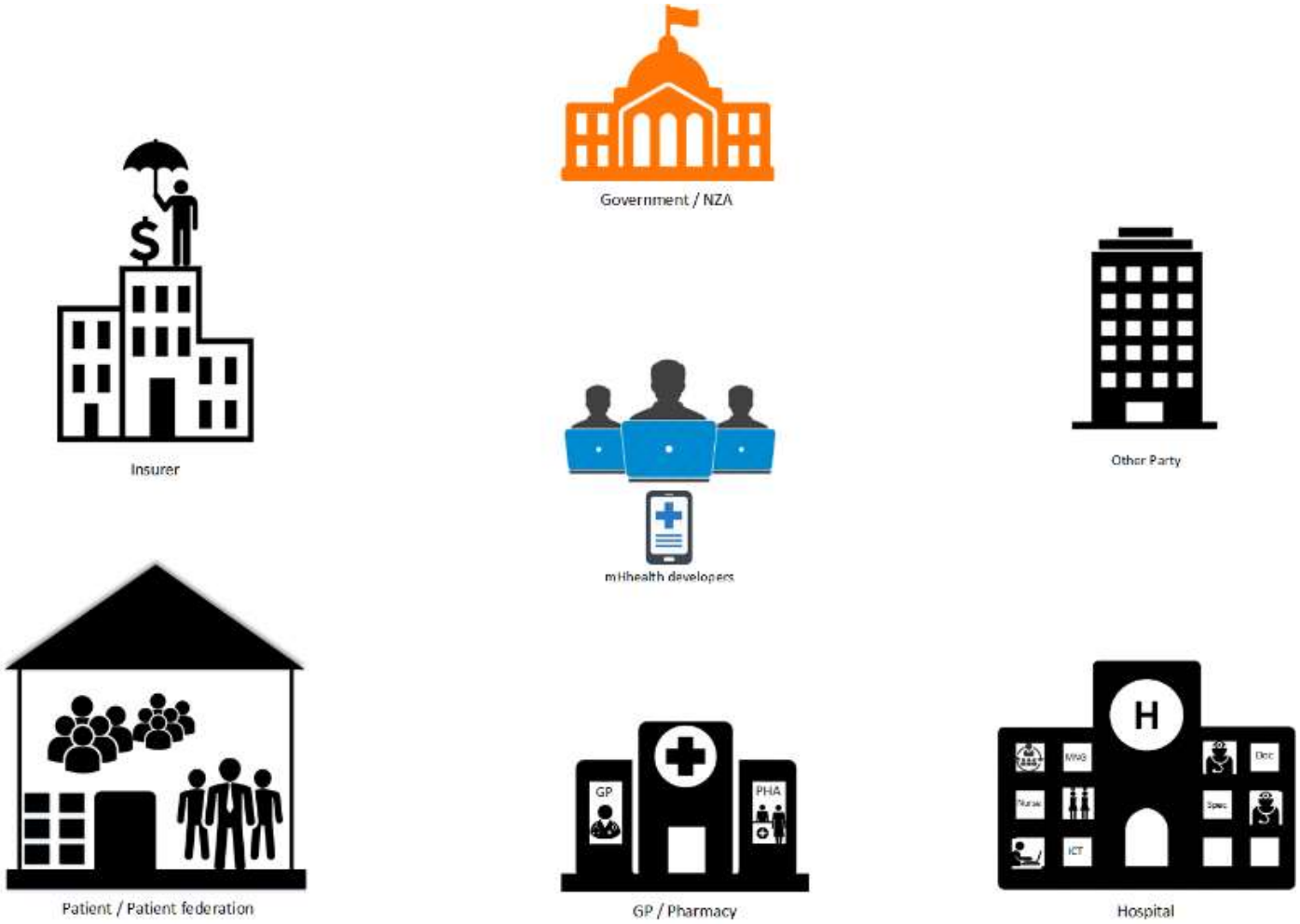

Figure 8: Interview appendix I: Overview of all stakeholders in the Dutch healthcare sector

Interview appendix II: The hundred-dollar test

Prioritization by weighing solutions against each other.

1. Imagine you have a hundred dollars to spend on developing these solutions.
2. Allocate your $100 across the solutions.
3. Keeping in mind that it is your money, but you will profit from the solution which get developed from your allocation.

Example

Barrier/Solution 2 is the most important to be realized in the short term in order to increase medical apps adopted in the market.

$30 – Barrier/Solution 1: Automated data entry from glucose meter to medical app.

$50 – Barrier/Solution 2: Develop guidelines so that insurer will reimburse medical app.

$20 – Barrier/Solution 3: More clinical trials to validate app effectiveness.

Interview appendix III: Barriers overview from literature

Table 9: Interview appendix III: Barriers overview from literature

	Barrier	Stakeholder	Solved Y/N	Comments
	Perceived usefulness and ease of use			
1	Functional deficiencies: lack of individually important functions; unnecessary functions; lack of customization	HCP, Patient, Insurer		
2	Complexity of app use, handling too complicated	HCP, Patient		
3	Small screen size, battery consumption, need to carry smartphone all time	HCP, Patient		
4	Time consuming (disruptive to workflow)	HCP, Patient		
5	Lack of decision support (to manage own condition)	Patient		
6	Lack of continuous monitoring	Patient		
	Dependability and evidence			
7	Accuracy, reliability and validity of sensors and systems	HCP, Patient		
8	Assurance: compliance, control, verification of data (appropriate content)	HCP, Insurer		
9	(Lack of) quality standards: app functioning should have an assured quality	HCP, Insurer		
10	Availability of the content	HCP		
11	Lack of clinical approval of the app	HCP, Patient, Insurer		
	Security, privacy and regulations			
12	Privacy (protection of personal private data, vulnerability to loss smartphone)	HCP, Patient, Insurer		
13	Lack of governance, app regulations	HCP, Patient		
14	Medicolegal issues: Implications if HCP failed to act on readings that had been transmitted. Professional security, clinical uncertainty.	HCP		
	Integration and interoperability			
15	Compatibility with the work process, HCPs can have different ways of working	HCP		
16	Lack of interoperability with other devices, apps, web portals	HCP, Patient		
17	Integration with current healthcare systems	HCP		

	Individual and experience			
18	Motivational and emotional barriers (lack of additional benefits, no joy of using app or smartphone, loyalty to keep using mobile app for therapy, stigma/blame/fatigue because being confronted with disease all day)	HCP, Patient		
19	Digital and health literacy levels: difficulties in using smartphone, unawareness of existence medical app for disease management, lack of professional experience, difference between younger/older/disabled people.	HCP, Patient		
20	Accessibility to a mobile device (young children, elderly)	Patient		
21	Visual, auditory and cognitive disabilities	Patient		
	Financial			
22	Apps must be cost-effective in their use	HCP, Insurer		
23	Implementation costs / available budget, increased cost of care. No cost compensation or reimbursement for implementation. Cost benefit ratio unacceptable (cost of smartphone, data plans, fee for using app).	HCP, Patient		

8.3 Appendix 3: Validation interview protocol

Go through all the individual items and answer the below questions as a validation of the structured overview created in Chapter 5.

1. Do the individual barriers relate to the barrier categories?
2. Are the solutions provided for the individual barriers clearly defined?
3. Do you agree with the choices in the 'Control' column?
4. Do you agree with the required stakeholders that are mentioned?

Extra information:

The extent to which medical app developing organizations are in control of a possible solution is divided into three gradations:

- The solution is fully controlled by the medical app developing organization (C);
- The solution is partially controlled by the medical app developing organization (P);
- The solution is not in control of the medical app developing organization (N).

In case a solution is partially controlled or not in control of the medical app developing organization, the column 'Required stakeholders' indicates the parties who are (partly) responsible for realizing the solution.