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Home elderly monitoring network built by smart-phone applications

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Abstract—*Improvements in information technology and reliability of web based applications along with availability of mobile devices with high computational power, capacious memories, high-resolution displays and open operating systems that encourage application development, have provided a suitable foundation for collecting, analyzing and delivering patients' vital data through health care applications as well as a reliable platform for establishing a portal to facilitate health care services. The capabilities of smart mobile devices have empowered realization of cheap yet high performing web-enabled solutions. The usage simplicity and availability of these smart devices have made them very well suited for home monitoring and care services of elderly and chronically ill population..*

The goal of this paper is to perform a case study on elderly community as well as patients with chronic diseases, to investigate the impacts and potential risks of Mobile Health Care Monitoring and patient centered health applications on their lives. The results and at a later stage the conclusion of this research are based on interviews which were conducted on elderly people with or without chronic diseases, developers who had a background in eHealth, and doctors with experiences within eHealth services. The interviewees were selected from different countries in order to obtain information from a broader audience using similar services. This study covers health and technical risks associated to home monitoring networks and eHealth care services from different aspects.

Keywords: MHCA (Mobile Health Care Application), VPN, elderly, Chronially ill, eHealth.

II. INTRODUCTION

Advances in information and communication technology (ICT) have enabled a fundamental reform of health care processes based on the use and integration of electronic communication at all levels. Furthermore, recent statistics show that, in developed industrialized countries, more and more people, from the entire age spectrum, live in households with mobile phones rather than traditional landlines; this means that they are becoming increasingly reliant on mobile phones and applications in different aspects of their lives. This change in life style along with new communication technologies can support a revolutionary transition of health care from its conventional institution-centered methods to patient-centered applications. As a result, many experts, such as informatics researchers and system designers, who previously focused on designing IT applications that addressed the needs of health care providers and institutions, are shifting toward patient-centered solutions and applications.

Therefore, in many developed societies it is widely accepted that eHealth, the use of information and communication technology (ICT) and processes in healthcare [1,2], will eventually be a crucial part of healthcare services and delivery [3–4]. Electronic Prescription (ePrescriptions/e-Rx) and Electronic Health Records (EHR), as examples of eHealth services, are well established and widely used in the Scandinavian countries; ePrescriptions were introduced in Estonia in 2010 [5,6]. Furthermore, providing care services and health support outside medical institutes to elderly people, who suffer from chronic diseases or may not have the ability to visit care institutes regularly, is the focus of many current researches and practices in eHealth. These services are particularly of great importance in societies with large elderly population and population ageing phenomenon; this phenomenon occurs when the median age of the population in a country rises because of higher life expectancy and/or lower birth rates. Sweden, Japan, and Germany are examples of countries, which are dealing with this phenomenon. Different practices and studies have shown the practicality of home monitoring in case of patients with chronic diseases; these researches demonstrate how such practices are beneficial for patients who suffer from chronic and long-term diseases [7-8]. In Denmark, a pioneer country in eHealth services, MedCom platform connects general practitioners to patients, which has enabled home monitoring and out-of-hospital services. Nevertheless, in order to fully integrate and establish eHealth services over the conventional care systems, and to encourage the society to welcome and use them, these services should develop to cover and serve the majority of the community including patients with different illness backgrounds, severity or conditions.

This paper sets out to investigate the comprehensive impacts and corresponding risks introduced in home monitoring networks, MHCAs and mobile health care services on the life of old people with or without chronic diseases.

The rest of this research paper is organized as follows. The following section presents the aims and objectives of the research along with related work and literature review. Section 3, demonstrates the methodology which includes the research process and methods to collect and analyze data. In section 4, the results and their analysis are presented. Section 5, discusses the findings, and finally Section 6 concludes the research. Furthermore, Appendix A contains the list of interviewees, and Appendix B details the interview questions.

III. AIMS AND OBJECTIVES

Literature reviews revealed that the solutions provided for health care applications and out-of-hospital care services are not developed based on well-studied use case analyses, part of it is due to the fact that there are enough research on the topic. Therefore, the main purpose of this project is to investigate and gather information on the workability and effectiveness of the Mobile Health Care Applications (MHCAs) according to the opinions of the targeted communities. This study looks into advantages and disadvantages of these applications, which are developed to provide e-Health care to chronically ill and/or elderly, based on conducted interviews with patients, physicians and application developers. The research also depicts the impacts on these demographics, and furthermore, it identifies the potential risks associated with the use of such services and applications.

This research, , since it's based on case studies, helps to find out to what extend healthcare applications and services may simplify the life of elderlies and chronically ill patients, and how well such services can provide a convenient life style for them as well as addressing the medical care and agile reaction in critical or emergency circumstances. In order to accomplish this goal, the study contributes by providing a thorough insight into perceptions, attitudes and concerns of chronically ill and/or old people towards healthcare and patient-centered applications, technologies and services.

A. Research question(s)

RQ1- what are the perceived impact factors of healthcare applications on elderly society and/or patients with chronic diseases and the healthcare providers/systems?

RQ2- what are the perceived risk factors associated with healthcare and patient-centered applications for the elderly community and/or patients with chronic diseases?

In order to answer the aforementioned research questions and elaborate on the investigation, the necessary data were collected from chronically ill and/or elderly community by means of case studies, as a way to conduct a qualitative research. Semi-structured interviews were used to collect data throughout this study. This type of interview allows interviewers to further investigate certain themes due to open-ended structure of the questions [9]. Moreover, after conducting the interviews, the research continues with analysis of findings and responses using the Qualitative Thematic Analysis method [10] through which it defines themes and concepts from the collected data, and finally it concludes by providing in-depth interpretations and discussions based on all the information.

B. Related work/Literature review

Due to the increasing use of telecommunication systems in medicine since late 1990s, there are many papers published in conferences and journals on the topic of healthcare applications and services. The following literature review shows that there are several ongoing and practical healthcare projects targeting elderly and chronically ill communities. It also depicts that, there are not enough investigations on the impacts and potential risks of such services, from those who have been interacted with such applications in different levels.

William Mann and Sumi Helal [11] researched how smart phones can positively affect the quality of life and independence of old people or those aging with or into disabilities. In [12] and [13], the use of new products and computer-supported care services along with their impact on elderly community were comprehensively addressed. These studies show that healthcare applications have the potential to positively influence the community of elderly and patients with chronic diseases. Darrell. West, in [14], studied the adoption of new eHealth smart phone applications and their impacts on medical treatment and care service delivery, and the fact that these applications may reduce the cost of health care systems. Chowdhury et al. [15] developed an RFID-based real-time patient management system for hospitals. The system facilitated automating and streamlining patient identification with the help of smart phones or PDAs. A research project at Harvard University [16], introduced a low-power wireless ad-hoc sensor infrastructure intended for emergency medical care based on .NET compact framework. The deployed application was able to store patients' information including their identities, health status and medical history. In the Nursebot project [17], researchers developed a mobile robotic assistant, which was used at a retirement community to remind elders about routine activities and guide them through their environments. Wang et al. [18]. implemented a smart phone application to help patients, mainly old people or chronically ill patients, avoiding common drug-intake mistakes such as over/under doses and troublesome drug interactions. The application, developed in .NET framework, served patients by reminding them to take the correct medicines according to the prescribed schedule and keeping intake records for later review by healthcare professionals. In [19], a method based on mobile data mining was developed to provide intelligent healthcare

support and facilitate blood pressure measurements. Boulos et al. [20], surveyed several smart phone applications aiming to help both old/chronically ill patients and healthcare professionals. Furthermore, they comprehensively described the development of a remote monitoring healthcare application within eCAALYX (Enhanced Complete Ambient Assisted Living Experiment [21]), in which data was collected by a patient-wearable garment with wireless health sensors, tagged with GPS location information from patient's smart phone and transferred to a network which was accessible by both the patient and the professionals in charge of remote monitoring. The collected raw sensor data was also used to identify higher-level health issues such as tachycardia and signs of respiratory infections.

IV. RESEARCH METHODOLOGY

This section explains the approach used in this research to collect and analyze the data.

A. Research process

Qualitative approach is adopted to conduct this research [22]. The qualitative approach is based on a case study on the elderly community and physicians dealing with this community. The benefit of qualitative method is that it helps researchers to explore problems in a specific area of concern and provides detailed understanding of a phenomenon in real life context [23]. According to Cresswell [22], case study is a qualitative approach in which the researcher often makes claims based on findings of practical perspectives. In this method, researcher may collect principal information and analyze this information to create patterns. Qualitative procedure is based on the obtained data and analysis of the data through unique steps. In this research, the phenomenon at question is the impact of MHCAs on the community of old people and their viewpoint on such services. The importance of this research is due to existence of little background of MHCAs and the fact that more in-depth information should be obtained in this area [22]. This approach provides researchers with a social constructionist worldview because of the centric role of interviews in this study and as the results are based on interaction with the main stakeholders in an open way [22].

A case study can be defined as an empirical method to investigate contemporary phenomena in their context [24]. In this research, the contemporary phenomenon is defined to be the impact of MHCAs on elderly community. According to Robson [22, 24], obtaining more information and knowledge about the current situation and processes of an area is the main goal of case studies. Each case study consists of five major steps [24]:

1- Planning to perform the study
2- Preparation to collect the necessary data
3- Data collection processes
4- Data analysis and evaluation
5- Composing the final report

B. Research Setting

In this part the research setting is defined with factors such as who, what, where and why.

The research setting in this study consists of the community of old people who live in different countries and have used one or more services included within the MHCA framework. This study focuses on a few of such services that have been used by old people or the ones with chronic diseases in different countries. Therefore, to cover all relevant aspects and to obtain data from different major perspectives, the participants are chosen from main three groups of stakeholders.

1- Old people or people with chronic diseases
2- General Practitioners or Specialists who are familiar with Mobile Health Care services/applications
3- Developers and Informatics researchers who are currently working on developing MHCAs

C. Research Process

1) Data collection procedure

In this research, transcribed interviews with main stakeholders were the main resource for collecting the necessary data. The interviews were set up as semi-structured interviews with open-ended questions. A common technique to conduct interviews in case studies is the semi-structured method [19, 24]. This approach is very useful as it allows the researcher to capture individual's motivation and understanding of a specific phenomenon. Moreover, semi-structured interviews ensure that collected data falls within the intended topics through predefined questions, and permit the interviewer to investigate more when required. Interview is preferred to large-scale survey as questions could be interpreted differently by stakeholders [25]. The semi-structured interview approach helped this research to investigate and understand under discussion topics in their real life context [26].

The semi-structured interview in this research was developed and categorized in three themes from the perspective of each stakeholder (1) "Advantages of using MHCAs", (2) "Disadvantage of using MHCAs", (3) "Technical or health risks involve in using MHCAs". The interviews were setup in forms of "how", "why" and "what" questions and consisted of a list of predefined open-ended questions based on the previous relevant work in the same area. The interviews were conducted according to the preference and availability of the interviewees, either via online services such as Skype and Google Hangouts or in their living/working environments. The main goal was to make the participants feel more comfortable in order to answer the research questions. Throughout the interview, when the participants were asked questions within the

aforementioned three themes, they were allowed to talk as much as they wanted about each of the questions and topics in an open way and to steer the path of the answers themselves.

Interviewees were selected from different stakeholder groups to gather comprehensive and rich data. Interviews usually lasted from 40 to 60 min, and interviewees were asked about the practicality and/or technical aspects of MHCAs. All conducted interviews were recorded, with the candidate's consent, to save time and ensure information integrity and availability. Each participant in this research had a different background and experience with the services, hence their response was different to each question in comparison with others'. In order to inspire the interviewees to elaborate on their responses, researchers had to improvise new relevant questions and provided positive comments throughout the interview. In order to have more effective interviews, an interview protocol consisting of date, place, name of the interviewer and interviewee, standard interview procedures, default and follow-up questions was used [22]. This protocol allowed the participant to spontaneously express their opinions in their own words. Furthermore, follow-up questions are very important as the interviewer can investigate certain ideas and experiences of each participant with a stronger focus. Follow-up questions also show the researcher's interest in hearing about the interviewee's opinions and ideas, which can make the participant more willing to elaborate on their responses [27].

In order to find in-depth answers to the first research question, old people with or without chronic diseases and doctors who had experience with MHCAs were mainly interviewed, although developers' insights enriched the overall conclusion. Furthermore, to investigate the second research question, interviews with doctors, and MHCA developers inferred the majority of required information, granting the fact that interviews with elderly group weighed in as well. The questions were designed to focus on the areas of great importance including usability, practicality, advantages/disadvantages, and difficulties of current system. The candidates were also asked what features or aspects they would like to see added or changed in the future. The main questionnaire, which was used as the base in all interviews, can be found in appendix B.

2) Data analysis procedure

Thematic data analysis was the method employed in this research to analyze the collected raw data. According to Braun and Clarke [25], this technique is effective to detect process and report various themes that exist in the data collected through interviews. Thematic data analysis was chosen as it has qualitative text interpretation attribute along with benefits of quantitative content analysis. In thematic method, all the information is analyzed strictly in steps.

1- The first step in analysis was to read, transcribe and understand the interviews conducted in the previous stage. Data analysis process started from categorizing and transcribing the interviews. In order to extract the required and significant information, all transcribed versions were summarized and interpreted according to their context, and the main and important keywords were highlighted.
2- Generate the initial codes by rewriting each answer into more identifiable code in order to document where and how patterns occur. In this study, to structure data into different categories and reduce the size of collected data for more efficient analysis, the answers to a specific question from each interviewee group were labeled while keeping the identity of the data.
3- The previously generated codes are combined and organized into a thematic system, which accurately portray the data. A code can belong to more than one theme. At this stage, the themes were clearly defined and the categories were inspected and analyzed to find the proper set and combination of data in order to answer the research questions.
4- Verification was the next step in order to check and make sure that each theme supports that data and if it is possible for that theme to break down to more themes. For some instance, researchers had to go back and look into the generated codes or even transcribed interviews to locate the missing data.
5- The definition and name of each theme was defined and its description was written.
6- In the final step, the themes which, were relevant and meaningful for this research were selected. The final phase was to summarize the obtained answers and write the report.

The interview questionnaire in this study consisted of twenty-one questions. Throughout the analysis process, depending on the available data and diversity of collected information on a specific question or topic, assignment of themes to each category was different, for some questions, there was only a single theme and for others there were multiple. In order to verify the correctness of the qualitative approach in this thematic analysis, a checkpoint list that is proposed in [28] was used.

Beside all the information gathered through interviews, and analysis of such data to extract answers to the research questions, other related studies in the same domain of this project were the variants of sources, which fed this research. The purpose of studying other related researches was to find premises that either support or contradict the ideas, which have been introduced within this project. These relevant reads provided insights and helped this study to safely deduce a more reliable and valid conclusion.

V. RESULTS

This section describes the results of this project, which are extracted by analyzing the conducted interviews, in order to answer the introduced research questions.

A. RQ1: Impacts of using MHCAs on its stakeholders

These impacts are given from the perspectives of different groups that are interviewed in this study: patients, care providers like doctors and healthcare application developers.

Moreover, the participants respond are based on experiences of using following mobile heath care application:

1- Heart rate measurement application,
2- Diabetes support applications,
3- Cataract detection application to prevent blindness.
4- Electronic prescription,
5- Respiratory rate detector and application,
6- Kidney function check-up application.

a) Improving the quality of life by increasing people's independency

Majority of the interviewed participants were reluctant to live in the elderly homes. They would rather stay at their own homes, as long as they can manage themselves and prevent health problems without the need of any caregivers, in order to keep their independence in life. One of the patients pointed out *"I need to check my cardiac rhythms and my heart condition continually, it is not possible for me to contact the doctor every day. Heart rate measurement application solved my problem and gave me the insurance of being monitored through health care system continually."* Another patient pointed out that *"The Respiratory rate detector application has helped me to overcome my sleeping problems and preventing uncomfortable breathing situations*".

One of the interviewees pointed out how unexpected problems had been addressed by the use of MHCAs *"We have access to nurses in specific times during each day but not always. Therefore, there are times that we do not need them but they are available, while sometimes when we need them they may not be in access. MHCAs decrease our concerns about on time treatments and offer quick reaction to different unexpected situations of diseases through quick access to the health center at any time."*

According to one of the participants who was suffering from a kidney cancer, *"MHCA helps me to find the best food diet in order to prevent the tumor from spreading further and faster. This is realized by instantly getting samples of my blood and urine after eating specific meals or fruits. Analysis of the collected samples provides the health center with the necessary data in order to get back to me and suggest the best diet."* MHCAs' mobility and high availability provide a full coverage for the detection of unexpected issues by discovering their early symptoms. This feature increases the confidence of patients in their ordinary life regarding their health in a very implicit and noninvasive way.

b) Prevent the development of a serious illness by providing realtime and constant monitoring data

According to one of the interviewees who uses heart rate measurement application: *"Usually the symptoms of my health problem appear when I am not at the doctor's office. The heart rate application has provided me the opportunity to save all the symptoms in real-time and my doctor is able to get them soon after and hence make the necessary decision and inform me*."

One of the interviewees pointed out that "*I could manage to prevent my malignant tumor from spreading to a great extent by monitoring its symptoms constantly and obtaining in-time and immediate recommendations and prescriptions from my health care providers*."

Considering the instant interaction between the patients and care providers, this approach could deliver the required information to get the immediate proper solution in unexpected situations.

c) Decreasing the commute time and cost for patients

This approach makes the health monitoring of patients independent from their geographical locations. Most of the interviewees were concerned about their struggles and inconvenient experiences to make it to the doctors' office on time. "*By using MHCAs we don't need to drive to the hospital, struggle to find a parking spot, and find our ways to the doctor's office*".

d) Decreasing the concerns of losing the patietns' background information

According to one of the patietns "*I don't need to remember the name of drugs or the amount of any prescibed medicine. I feel completely secure and stressless with MHCAs. They gave us an easy and organized way of keeping all the process of our treatment with more details in one place."* On the other hand, this software allows the hospital and healthcare professionals to collect their patients' health information instantly to have an accurate and complete analysis of the treatment processes.

According to some of the interviewed doctors, *"having access to the complete history of each patient's health problems, is a valuable way to choose an optimum diagnosis."* In another interview, a physician pointed out, *"In the traditional healthcare system, one of the main problems was the lack of information on patients' medical background and cured problems."* Furthermore, another interviewee mentioned *"It is hard to find the medical history of a patient who visits once a year. Moreover, it is not possible to rely on the patient's memory to remember the exact information."*

In fact, this approach sheds light on the dark spots of the treatment processes by connecting similar symptoms from different parts. This is possible nowadays due to the accessibility to a huge source of information on health issues and existing processes to cure them, from different places of the world.

e) Efficient utilization of healthcare staff in monitoring of elderly people and patients with chronic diseases

One of the interviewed doctors believes that "*This approach helps healthcare providers to find better solutions backed up with evidence-based results among the existing similar experiences across the system. This enables us to schedule our time efficiently, review patients' medical history carefully, find better solutions in more convenient ways, and share their experience with other professionals*", efficient utilization of healthcare staff could increase the satisfaction of both health providers and patients as well.

f) Decreasing the amount of inessential tests

In some occasions, doctors have to re-do the same tests multiple times on patients due to lack of access to their prior test results. This means a waste of time for both the patient and the physician, which also results in an increase in the cost of treatment. Besides, it may cause an unpleasant treatment experience for the patient. One of the interviewees from care providers group mentioned that "*without lab results, it is hard to identify the issues even in the obvious cases. MHCAs solve such issues by keeping each patient's laboratory results stored and available for further analysis during the relevant period."* In addition, one of the patients said, "*Sometimes, I do not trust the opinion of just on doctor or the physician who is handling my test results. In order to be sure, I would prefer to get other physicians' opinions as well. In such cases, MHCAs may save us from re-doing the test, as we can simply present or share the results of tests and the complete medical history with another doctor."*

g) Empowering the inexperienced doctors

The interviewed doctors believe that the use of these applications and having a medical data repository may provide the accessible platform to train the newly graduated doctors; *"They may gain access, by the consent of the patients, to the available data and get real and empirical experience about different diseases and available or experimental treatment processes. In addition, they may be able to provide and present their medical practice results in a comprehensive medical data bank in order to receive feedback or even praise."*

h) Reduction in the amount of paper work

By migrating from traditional health care systems to advanced eHealth system built on MHCAs, one can get rid of all the hard copies of patient's data; this advantage applies to both the professional care providers and the patients. In addition, patients were happy because of this opportunity,*"MHCAs decrease my concern about keeping the doctors' prescription; it is easy to have easy access to all the medicines that I am taking, without any need to collect doctors' prescriptions."*

i) Reducing the concerns about getting the wrong medications

All the participants were hundred percent sure that they would use the right medications with MHCAs. One of the patients noted, *"With the use of MHCA, the prescription is sent to the pharmacy automatically, there is no need to doubt in getting the wrong medication due to the incorrect interpretation of doctor's handwriting."*

j) Patients may improve their knowledge on their diseases with common symptoms

Majority of participants described that "*Even though I don't mind to share my information with others, but it is more reasonable to give access or permission to reliable and trustworthy people to access my health information if it could help them."*

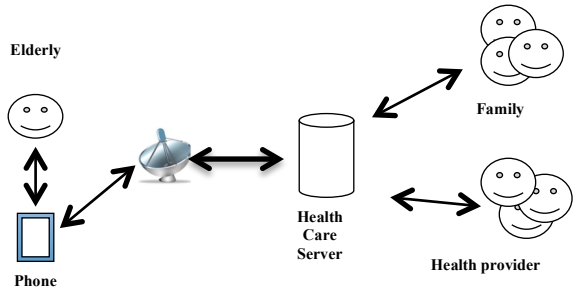

Figure 1: Patients can share their health status and information with both healthcare providers and family members.

One of the interviewees *mentioned, "Finding a similar case through MHCAs helped me to cope better with my disease. It helped me to increase my hope and decrease my stress level. It also helped me to get rid of the overwhelming concern that I may not be able to overcome the disease. After learning about the similar case with a successful cure, I obtained the necessary confidence in my treatment process. This was a great way for me to learn from others' experiences who were on the same journey as I was."* Furthermore, MHCAs provide a proper way to investigate the general reports and results of diagnosed diseases and useful medications, using anonymous data access scheme. This advantage generates hope in patients and to some extent guarantees that their problems are controllable and manageable by following the similar treatment procedures adapted from other similar cases.

k) Involving patients in their process of well-being

These services increase collaboration between the patients and healthcare teams. One of the patients pointed out that, *"Getting familiar with the new technology is a part of modern society. Sooner or later everyone in the society will start participating to recognize and improve their health life factors."* To this end, patients are engaged to increase their knowledge of how to use the MHCAs and to obtain more awareness about specific diseases, their symptoms and the

methods to control them. Moreover, family members of patients can join in this group and assist them in some cases. In fact, MHCAs can exploit the huge existing potential within human beings to make them active and aware for taking care of their own health instantly.

One of the developers talked about "*offering a video conferencing solution to involve both patients and care providers for getting updates, in order to meet the efficient ways of health care processes*". However, this approach increases the complexity of security from the MHCAs stakeholders' point of view in cases when they do not have seamless and reliable access to the health care system due to network issues such as limitation of the Internet coverage. This problem may worsen if they need to engage in multiple video conferencing calls.

Developers address these issues by "*centralizing sensitive data on the secure server and providing local access between this server and the stakeholders with poor Internet connections, as shown in Figure 2*". In addition, "*Developers have employed HTML5 to resolve issues with regard to smart phone OS variants and updates. User interfaces in HTML5 can be easily adapted on different smart phone devices*".

Figure 2: local Connection between clients with poor network connection and sensitive database.

B. *RQ2: Risks of using MHCAs*

Here we highlight some of the risks involved in using MHCAs. The risks are mainly based on the processing of the gathered data from interviewees.

a) Accessiblity varies for patients from different economical classes

According to healthcare providers and developers, "*these technologies are growing faster among the patients with a better socioeconomic status*". A healthcare provider interviewee pointed out "*MHCAs have developed more in private smaller hospitals which mainly accommodate patients with good economic status rather than hospitals with much larger number of patients with poor economic status*".

b) MHCA's usres privacy and security threats

One of the key risks related to MHCAs is the use of unsecured wireless connections by patients on their smart phones. According to one of the developers in the interview "*During the past few years the availability of free and public WiFi hotspots in cities have made it easier for criminals and hackers to attack the accessed or sent data on the air, also the risk of any smart phone being infected by malwares is much higher. Hence, it's a necessity that all the MHCAs encrypt all the collected data prior to transfer.*" In addition, one patient, who uses heart rate measurement application, shared his concerns about the privacy of MHCA. According to him, *"It is important to me that the application keeps my health records and data safe and private."* Even though patients like to use the MHCAs to monitor and manage their health issues, its privacy and security has a main role in building the trust in them and attracting them to be a user of this service.

c) Lack of sufficient knowledge to use the new technology

According to the participants, Patients' lack of proper information and knowledge on how to obtain and interact with the MHCAs is one of the challenges for developers. One of the patients mentioned, *"Some functions of MHCAs are not easy to understand. Sometimes I need to look at the manual from time to time in order to remember the steps of the process."* Since the majority of the consumers of these applications are older than 60 years old, developers have to find ways to make it easier for these consumers to use the services. Creation of a friendly and simple user interface is one of the methods to attract the elderly community.

d) Interuption in the transfer of healthcare data

One developer mentioned that the connection between healthcare provider and patients may be interrupted due to a few reasons: (i) malfunctioning of the patients' mobile devices, (ii) poor internet connections, (iii) power outages or any other intermediate device malfunctions. These issues may prevent the complete transfer of the healthcare data to the health center or may cause a delay in professional care processes on the appropriate time in urgent cases.

e) Lack of emotional contact

Some patients pointed out that "*they can manage their health problems with less stress while visiting their doctors personally and regularly than managing these issues through MHCAs*". In addition, some health providers mentioned, "*they can obtain more information and do more experiments when patients are physically available in their*

offices".

f) Missing data

According to the developers "*delivering highly secured products, which may provide safe and reliable environments, is one of the top priorities in delivering such applications*". Enabling MHCAs with the aforementioned features will pave the way to an easier acceptance by the majority of patients. On the other hands, if patients experience issues with regard to safety and privacy of MHCAs, they will stop adopting these services in their lives. Moreover, the security and privacy of the transferred health data may be jeopardized while personal email addresses or USB flash drives are used. According to one of the interviewed doctors *"The main question for me is that how I can assure that the transferred data is intact and genuine? The data may be attacked and altered by hackers and smart phone malwares."* In addition, one patient mentioned that *" I am always worried to set a password for my smart phone, because whenever I am under stress I easily forget the password. On the other hand, I am also worried not to protect my phone with a password as I may miss my smart phone and hence my data will be available to others."*

g) No trust in a new service

The weakest points in security and privacy matters of MHCAs are the health providers and patients themselves. Some of interviewed patients pointed out *"We cannot trust a new system which has not yet been completely proven secure and working."* This shows that due to lack of knowledge on the MHCAs and their features, some patients are not looking into them as a great option.

VI. DISCUSSION

The migration of traditional health care systems to mobile health care application systems is an important process that requires meticulous observations from different aspects. This approach provided the study with extensive information in order to address the research questions. The main users of MHCAs are old people and ¬patients with chronic diseases, which consisted %40 of all interviewees. The other two groups were doctors (%30) and developers (%30). The main impacts of this migration are gathered in the result section of this study. The collected information about the first interview question, together with our analysis on the responses from interviews, provide fairly sufficient evidence to obtain some insight on the importance and priority of these impacts. Hereby we describe the importance and priority of introduced impacts for MHCAs in Section IV.

A. Priority analysis of impacts of using MHCAs

To perform this analysis, we categorize the impacts in three main groups, namely (I) Process optimization and complexity reduction, (II) New software application services, and (III) Improving the reliability and security of medical services.

In group (I), the impact items (g), (i), (h), and (k) from the Result Section, are clearly addressing the efficiencies and optimization that yield by using MHCAs. These items introduced in this group are not the main goal in developing the MHCAs and have less importance in deriving the software requirements. As an example, one can think to prevent unnecessary repetition of blood or other medical tests by properly keeping and monitoring the previous test results in the system and their expiration dates as well as the correlation between them in time.

The second most important group, i.e. (II), determines the focus in the design and extracting the system requirements, including impacts (a), (b), (c), and (l). Clearly, it has a very high level of importance that MHCAs' mobility and high availability provide a full coverage for the detection of unexpected issues by discovering their early symptoms. This feature increases the confidence of patients in their ordinary life regarding their health in a very implicit and noninvasive way. For example, as pointed out in the result section, MHCAs may offer an independent life for elderly and disabled people by taking advantage of connected portal system. Moreover, automated system in providing different facilities such as remote vital sign monitoring and diagnosis can considerably mitigate the chance of being in a risky situation for elderly people. As will be discussed shortly, MHCAs can offer the required ingredients for realization of this healthcare foundation for elderly community and this impact has high importance in the system analysis. Furthermore, we found that MHCAs could provide a rich information bank gathered from patients' healthcare data globally. MCHAs with such a growing database can offer the Possibility of performing complicated post-processing algorithms established on graph theory (realized by connecting postulated diseases and observed symptoms in a graph diagram) and predicting the behavior of data in time and different geographical areas. In addition, MHCAs can speed up the decision making after investigating pre-collected information and getting the specific lab results much faster than before. Widely available high speed networks together with capable mobile equipment and advanced software applications can make the realization of this goal very likely.

Finally, in group (III), we have impacts with the highest priority and importance in the implementation of MHCAs consisting of impacts (d), (e), (f), and (j). These impacts must be taken seriously in the system development and software requirement derivation since the users of MHCAs are very concerned about them and they do not show any tolerance in facing any issue corresponding to these impacts. For instance, it is clear that informing conflicts of prescribed medications to doctors, which helps them to prevent the patients from dangerous consequences of drug misuse by fast reaction, has a very high priority in the design of MHCAs. In fact, a large number of mistakes such as allergy

reactions and side-effect problems can be properly handled by introducing MHCAs, which are very crucial. Besides, delivering right medications to corresponding patients by detecting their barcodes is a systemized approach introduced by MHCAs can be considered as one of the impact with very high impotence. This service assures patients that the delivered medication is precisely the original intended prescription for them. MHCAs can also provide a considerable help in detecting most of health problems in their first stages by considering their symptoms and using the correlation between the new observations and the available data in the bank.

B. priority analysis of risks

Advances in responsiveness and memory capacity of smart phones as well as software applications has leveraged the wide usage of MHCAs in moving from the traditional way of health care to its modern approach. In particular, the progress in data connection rates has also influenced this transition significantly. A close collaboration between health providers and patients is inevitable to cope with the (hardware and software) complexity and variety of solutions for different circumstances in an MHCA.

As discussed in Section IV, even though these technologies have offered a lot of simplicities and useful features, they have also introduced some risks inevitably. We split the risks introduced in the Result Section into three groups: (I) Risks in transition from conventional to MHCAs (II) Risks in protecting user private data (III) Risks in hardware and software malfunctioning and defective tools. The grouping is performed in order to show the importance. The highest priority and importance is given to the latter, i.e. (III), and the first group is considered to cause the least concerns in the system development.

In group (I), the following risks: (a) Accessibility for patients from different economical classes (c) Lack of sufficient knowledge to use the new technology and finally (e) Lack of emotional contact, can be considered as being described previously. As seen, this group is mainly addressing the issues involved in transition from the conventional approaches and schemes to modern techniques known as MHCAs. To this end, training and helping users to lean and catch up with the new tools and getting used to the new facilities introduced in these systems have the highest importance to provide a smooth transition. By focusing on the gathered information from interviews with doctors, we understood that all of them were interested in applying MHCA technologies instead of following the traditional or conventional methods of treatment. Indeed, they found these applications very useful from two perspectives. First, they are useful to improve the healthcare life of people through getting them involved in every part of their healthcare processes. Second, these services are very efficient to enhance physicians' knowledge about the effective methods of treatments, which were practically proven by other specialists. Interestingly, MHCAs provide such an opportunity to doctors to share their knowledge with other co-workers in different parts of the world through portals that are equipped with advanced search, filtering and post-processing tools.

The second group (II), is dealing with the users and other stakeholders' personal information and data. This group includes (b) MHCA's users privacy reveal and security threats (f) Missing data. The concern highlighted in this group has been taken seriously from both hardware and software perspectives and many challenges have been devoted to decrease and mitigate these kinds of risks for MHCAs.

The last group (III), contains the following risks introduced in the results: (d) Interruption in the transfer of healthcare data (g) No trust in a new services, addressing the network reliability such as mean average time between failures. MHCAs are required to pass several meticulously designed and checked procedures and tests in order to assure safety and reliability of these systems. In fact, whenever a system is targeting for health care market, this step is the most time-consuming and cumbersome development process stage. More precisely, this limitation will impose considerable elaboration in the hardware and software implementation. MHCAs can generate warning and trigger signals for informing emergencies by monitoring patients constantly in a real-time fashion.

The analysis of the gathered results revealed that 100 percent of participants in this research study (four patients, three doctors and three MHCA developers) were satisfied by MHCAs, even though they pointed out some negative factors of using MHCAs and highlighted their expectation to overcome the problems. Another interesting point that we extracted from the participants' responses was their higher tendency to use MHCAs when they faced more severe diseases. In fact, they liked to monitor their progress of treatment continually to prevent its development. In other words, when the diseases are crucial, it is more important to monitor them constantly and this opportunity can be provided by MHCAs.

C. The importance of impacts versus risks

Interestingly, our grouping strategy has highlighted the high correlation between the priority of impacts and risks. More precisely, the highest priority or importance is given to "Improving the reliability and security of medical services" among the categories for impacts and similarly in the risk analysis we have assigned the last group "Risks in hardware and software malfunctioning and defective tools" the highest importance, intimately dealing with the network and provided service reliability. Accordingly, the lower importance is considered for "New software application services" corresponding to the first group in the risk analysis "Risks in transition from conventional to new MHCAs". In other words, the first group of impact has no serious risk involvement and the main parts of risks are relevant to the last two groups of the impacts.

D. Threats to the validity of the results

Here some concerns involved in the validity of results in a general perspective as follows.

a) Insufficient number of samples

In a statistical data gathering and analysis process, access to adequate data is necessary to establish solid results statistically but since we were facing limitations in running large number of interviews, we have to consider the possibility of not having a rich enough database that can absorb the available dimensions and flexibility in the data. Main limitations were the availability and the schedules of the participants. Another limitation was being biased by the geographical confined views rather than getting access to a decent diversity by performing the interviews in different geographical places.

b) Lack of wide range of people in the interveiws

Despite our efforts to find people from different parts of the society and reach a rich gathered data for drawing the results, there might still be possibilities that we have missed to include or cover the perspective of some groups in the results of interviews.

c) Misinterpretation and misunderstanding caused by different generatoin of people in the interveiws

Since the IT revolution in the last two decades have created a significant gap between new and old generations, we experienced the side effects of this gap in our interactions with elderly people who are from older generation.

VII. CONCLUSION

The importance of research and study about mobile healthcare systems and their relevant applications is because these areas are tightly bound to human's health, which is a sensitive and crucial area. Therefore, all aspects of these technologies should be investigated, understood, analyzed, planned and precisely implemented.

The impact analysis in this research categorizes the enumerated impacts in the three groups according to their importance: (I) Process optimization and complexity reduction, (II) New software application services, and (III) Improving the reliability and security of medical services. Furthermore, based on these groups the risks are split into: (I) Risks in transition from conventional to new MHCAs (II) Risks in protecting user private data (III) Risks in hardware and software malfunctioning and defective tools. The results and the discussion show the corresponding relation between introduced groups of impacts and risks. More precisely, the impacts with high importance cause the risk with high importance.

The combination of advantages and disadvantages of MHCAs mentioned in Section IV offers a detailed response to first research question through which impacts of such services on elderly community and healthcare providers were questioned. Furthermore, the Section IV identifies the potential risks of using such healthcare services and applications, and reflects the opinions of interviewees on possible solutions to eliminate or mitigate the recognized risks, as a response to second research question.

Throughout this research, it became apparent that eHealth and MHCAs are on the rise, as several clinicians and allied health workers have already adopted smart devices in a diverse range of practices. Analysis of the data extracted from interviews encourages a bright future and high satisfaction rate for eHealth care services among old people and those with chronic diseases. Most of the interviewees in this study were happy with the provided services within this area and were hopeful to see more additions in the near future. Physicians were also positive and excited about the available services. They indicated how these services have enabled them to review their patients' medical background easily and quickly. They can run searches to find similar existing cases in the system, or to get suggestions from other successful professionals, even from the other side of the world. In fact, according to interviewees, MHCAs aim to gather a rich source of patients' health information to help with treatment of patients around the globe.

On the other hand, participants within all interviewed groups also had some concerns about security, privacy, integrity and accuracy of the collected, transferred and archived data. The general demand from eHealth service developers and designers is to manage the privacy and security risks by employing robust privacy and security policies, proactive and preventative approaches as well as well-implemented detection and response capabilities.

To sum up, this research indicates that the impact of moving towards eHealth care services and MHCAs on elderly community is mainly positive and progressive with few concerns in the area of security and privacy. Liable and responsible design, development, implementation and practice can help to eliminated or mitigated these issues and concerns.

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IX. REFERENCES

[1] Gunther Eysenbach. What is e-health? Journal of Medical Internet Research ,3(2), 2001.

[2] ICT for Health, Europe's Information Society, http://ec.europa.eu/informationsociety/activities/health/whatisehealth/index en.htm. What is eHealth? , Last updated 2011-03-28

[3] European Commission, Inforamtion Society and Media. eHealth in Action, Good Practice in European Countries , 2009.

[4] Gartner on behalf of the Swedish Ministry of Health and Social Affairs. eHealth for a Healthier Europe . Swedish Presidency of the European Union, 2009.

[5] SLIT-group (Landstingens IT-strateger/IT-chefer). eH¨alsa i landstingen , 2010.

[6] L¨akemedelsverket (Swedish Medical Products Agency). L¨akemedelsboken , 2011-2012.

[7] R. A. Clark, S. C. Inglis, F. A. McAlister, J. G. F. Cleland, and S. Stewart. Telemonitoring or structured telephone support programmes for patients with chronic heart failure: Systematic review and meta-analysis. British Medical Journal , 334(7600):942–945, 2007.

[8] A. Kashem, R. C. Cross,W. P. Santamore, and A. A. Bove. Management of heart failure patients using telemedicine communication systems. Current Cardiology Reports , 8(3):171–179, 2006

[9]]F. Shull, J. Singer and D.I.K. Sjøberg, "Survey of Data Collection Techniques", in the Guide to Advanced Empirical Software Engineering, London, United Kingdom, Springer, 2008, pp. 13-14

[10] P. Mayring.(2000 , june). " Qualitative Content Analysis." Forum Qualitative Sozialforschung / Forum: Qualitative Social Research,. Vol (1), Art. 20, http://nbn-resolving.de/urn:nbn:de:0114-fqs0002204.

[11] W. Mann and S. Helal, "Smart Phones for the Elders: Boosting the Intelligence of Smart Homes," Proc. AAAI Workshop Automation as Caregiver: The Role of Intelligent Technology in Elder Care, AAAI Press, 2002, pp. 74–79.

[12] T. Hirsch et al., "The Elder Project: Social, Emotional, & Environmental Factors in the Design of Eldercare Technologies," Proc. Conf. Universal Usability, ACM Press, 2000, pp. 72–79.

[13] S. Consolvo et al., "Technology for Care Networks of Elders," IEEE Pervasive Computing, vol. 3, no. 2, 2004, pp. 22&ndash,29

[14] Darrell West , " How Mobile Devices are Transforming Healthcare, " Issues in Technology Innovation, May, 2012.

[15] B. Chowdhury and R. Khosla, "RFID-based Hospital Real-time Patient Management System," in proceeding of 6th IEEE International Conference on Computer and Information Science, Melbourne, Australia, pp. 363 - 368, July, 2007.

[16] Malan, T. Fulford-jones, M. Welsh, and S. Moulton, "CodeBlue: An ad hoc sensor network infrastructure for emergency medical care," in Proceeding of International Workshop on Wearable and Implantable Body Sensor Networks, London, 2004.

[17] M.E. Pollack et al., "Pearl: A Mobile Robotic Assistant for the Elderly," Proc. AAAI Workshop Automation as Eldercare, AAAI Press.

[18] Mei-Ying Wang, J.K. Zao, P.H. Tsai, and J.W.S. Liu, "Wedjat: A Mobile Phone Based Medicine In-take Reminder and Monitor," in Proceeding of 9th IEEE International Conference on Bioinformatics and BioEngineering (BIBE '09), Hsinchu, Taiwan, pp. 423 - 430, June 2009.

[19] P.D. Haghighi, A. Zaslavsky, S. Krishnaswamy, and M.M. Gaber, "Mobile Data Mining for Intelligent Healthcare Support," in proceeding of 42nd Hawaii International Conference on System Sciences (HICSS '09), pp. 1 - 10, Clayton, 2009.

[20] Maged N Kamel Boulos, Steve Wheeler and Ray Jones, "How smartphones are changing the face of mobile and participatory healthcare: an overview, with example from eCAALYX," 2011

[21] Kamel Boulos MN, Castellot Lou R, Anastasiou A, Nugent CD, Alexandersson J, Zimmermann G, Cortes U, Casas R: "Connectivity for Healthcare and Well-Being Management: Examples from Six European Projects.", Int J Environ Res Public Health 2009, 6(7):1947-1971.

[22] Cresswell,J. Research Design - Qualitative, Quantitative, and Mixed Methods Approaches, SAGE Publications, ISBN 9781452226101, 2013.

[23] P.Runeson and M.Höst, (2009 , April), "Guidelines for conducting and reporting case study research in software engineering.", Empirical Software Engineering,Volume 14 Issue (2), pp. 131 - 164. Available:http://www.rbsv.eu/ [2014]

[24] Robson,C., Real World Research. Blackwell, 2002.

[25] Braun, V. and Clarke, V. (2006) Using thematic analysis in psychology. Qualitative Research in Psychology, 3 (2). pp. 77-101. ISSN 1478-0887

Appendix A

Table of interviewees

	Participant	*Application*	*Country*
1	Patient	-Heart rate measurement application -Electronic Prescription -Diabetes assistance applications	Canada
2	Patient	-Diabetes assistance applications -Electronic Prescription	United States
3	Patient	-Kidney function check-up application -Electronic Prescription	United States
4	Patient	-Detecting Cataracts application - Inspiration rate application	Canada
5	Doctor	-Hear rate measurement application	Canada
6	Doctor	-Diabetes assistance application	Iran
7	Doctor	- Cataracts application	United States
8	Developer	- Electronic Prescription	Canada
9	Developer	- Diabetes assistance applications - Electronic Prescription	United States
10	Developer	- Cataracts application - Hear rate measurement application	United States

APPENDIX B

Interview questions

Questions from the Patients	
1	Describe why, how, and when (how often) you use the mobile health care application (MHCA) on your smartphone?
2	Describe the main advantages of the MHCAs based on your usage experience. In other words, what good things can you point out about this application?
3	What are the problems, negative or bad aspects that you have faced when you are using the MHCA?
4	Have you met with your doctor less frequently since you started using this application? Why? (Positive/Negative)
5	In which situations you prefer to visit a doctor in person rather than reaching him/her via the MHCA instead? Why? Please elaborate on the reasons.
6	Are you worried about sharing your personal health information through the MHCA? Why does this raise your concern? Could you please explain how it can threaten your privacy?
7	Which of the following features are more important from your point of view as a user of the MHCA? • User friendly graphical interface (simple menu and appearance) • Privacy protection and personal information securities • Price (cost to buy and extra charge to update and internet connection fee) • Reliability (trustable and accurate results with low false alarm) • Constant (seamless) connectivity through Internet or other telecommunication networks to get access to doctors or other medical resources.
Questions from the Doctors	
1	What MHCAs are you using in your clinic? Describe how you are using these MHCAs?
2	What kind of information you are getting by using these applications?
3	What do you do with collected information? (Make decisions / Storage)

4	How do you communicate with your patients while you use these MHCAs? • Using applications • Phone meetings • Personal meetings (is the frequency of meetings decreased?)
5	What are the main advantages that you have experienced by using these MHCAs?
6	What are the disadvantages or negative things that you can point out based on your experience in using these MHCAs? Any health related risks?
Questions from the Developers	
1	How did you do requirements elicitation? Functional/non-functional (quality) requirements (did the person you talked with find it necessary and important?)
2	Do you contact with users during the project?
3	Acceptance testing with users?
4	What are the major risk factors that you can point out for the implementation of an MHCA (product and process)?
5	How did you handle the risks in the current application (product risks and process)?
6	Which measures did you take to prevent the risks?
7	How is data handled protected in the system (security and safety perspective)?
8	What are the main introduced features to assure patients about security of their information and protecting their privacy?