eTELEMED 2014

The Sixth International Conference on eHealth, Telemedicine, and Social Medicine

ISBN: 978-1-61208-327-8

March 23 - 27, 2014

Barcelona, Spain

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Foreword

The Sixth International Conference on eHealth, Telemedicine, and Social Medicine (eTELEMED 2014), held between March 23-27, 2014 in Barcelona, Spain, continued a series of events related to advances in techniques, services, and applications dedicated to a global approach of eHealth, including a regard on federated aspects considering the mobility of population, the cross-nations agreements, and the new information technology tools.

We are facing the generalization of digital society across multiple social areas. The globalization imposes the revision of the health costs a society can support. The progress in difference domains, such as image processing, wireless communications, computer vision, cardiology, and information storage and management assure a virtual team to access online to the latest achievements.

Processing medical data now benefits from advanced techniques for color imaging, visualization of multi-dimensional projections, Internet imaging localization archiving as well as from a higher resolution of medical devices.

Collecting, storing, and handling patient data requires robust processing systems, safe communications and storage, and easy and authenticated online access.

We assist to an unprecedented and rapid deployment of use of electronic imagery, navigation portals, positive attitude on telemedicine, distributed surgery teams, tele-cardiology, and remote medicine. Development of wireless homecare, of special types of communications with patient data, of videoconferencing and tele-presence, and the progress in image processing and data protection increased the eHealth applications and services, and extended Internet-based patient coverage areas. Social and economic aspects, as well as the integration of classical systems with the telemedicine systems, are still challenging issues.

We take here the opportunity to warmly thank all the members of the eTELEMED 2014 Technical Program Committee, as well as the numerous reviewers. The creation of such a broad and high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to eTELEMED 2014. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the eTELEMED 2014 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that eTELEMED 2014 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in the areas of eHealth, Telemedicine, and social medicine.

We are convinced that the participants found the event useful and communications very open. We hope that Barcelona, Spain, provided a pleasant environment during the conference and everyone saved some time to enjoy the charm of the city.

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Wearable Recognition System for Sports Activities

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Abstract— **Physical activity is a major part of a user's context for wearable computing applications. The system should be able to acquire the user's physical activities by using body worn sensors. We want to develop a sports activities recognition system that is practical, reliable, and can be used for health-care related applications. We propose to use the axivity device which is a readymade, light weight, small and easy to use device for identifying basic physical training activities (i.e., using elliptical trainer, butterfly, bench-press and pull down) and different swimming styles (i.e., dolphin, back-stroke, breast-stroke and free-style) using decision tree classifier, Averaged one-dependence estimators (AODE) and Neural networks. In this paper, we present an approach to build a system that exhibits this property and provides evidence based on data for 8 different activities collected from 20 different subjects. Our results indicate that the system has a good rate of accuracy.**

Keywords- Physical activities; accelerometer sensor; classifier.

I. INTRODUCTION

Human activity recognition by using body worn sensors has received attention in recent years. An activity recognition system in health care support, especially in elder care, long-term health/fitness monitoring, and assisting those with cognitive disorders is demanded. Therefore, recognizing human physical activities with body worn sensors is not a new research field; most research has already been done in this area. We can identify users' physical movements using a body movement suit [2]; we also have other research projects where researchers identify the users' physical activities using some sensors like [3][4][5][6][7][8].

With some diseases like diabetes, heart problems, mentally disabled persons, elderly patients are required to perform some physical activities or training exercises in order to make them physically fit. Similarly, in some cases, patients need to be monitored by nurses/trainers which is very time consuming and expensive.

Modern day lifestyle has lead to various physical and mental diseases such as diabetes, depression and heart diseases as well. According to the World Health Organization, there are at least 1.9 million people annually dying as a result of physical inactivity [10].

Although people are aware of the importance of exercise, there is a lack of motivation due to their busy schedules. People need to be urged and reminded about physical training exercises. Probably automatic and personal reminders can be very helpful if they can monitor one's physical training exercises and persuade people to perform them regularly.

Activity recognition technology can tackle this problem as it is able to monitor an individual's physical training exercises and their duration in order to estimate how much calories are being consumed on a daily basis. Those systems can also provide recommendation when they fail to complete enough exercise and it also encourages people to conduct more activities [12][13][14].

In some cases, especially in heart diseases, physical activities are also required along with the physiological information for doctors in order to examine their patient's conditions when he is away from the doctor's clinic [19].

We want to develop an activity recognition system using a minimum amount of sensors which should be able in identifying different physical exercises(using elliptical trainer, butterfly, bench-press and pull down) and different swimming styles (i.e., dolphin, back-stroke, breast-stroke and free-style).

In our research, we want to prove that it is possible to identify the aforementioned activities by using a 3D accelerometer. In next section, the related work will be discussed. Hypothesis and research question will be discussed in the section III. Experimental methodology will be discussed in the section IV. Evaluation will be discussed in the section V, and conclusion and future work will be in the last.

II. RELATED WORK

There are several ways to recognize a person's physical activities. One way is using cameras to visually detect people's motion [15][16].

The drawback of this solution is that a large number of cameras would be required in order to monitor a moving person. This system would also need to be designed to compute information from each camera and deal with other factors such as light, distance and angle, which make the system impractical.

Researchers already have identified various physical activities using wearable sensors like sitting [3][6][7][8], standing [3][6][7][8], lying [6], walking [3][4][5][6][7][8], climbing stairs [3][4][6][7][8], running [5][7][8], cycling [5] [8], strength training [8], etc. However, for their recognition system, they have used more than one sensor. For example, some researchers identified around 20 activities using 5 sensor boards [8]. They identified walking, walking carrying items, sitting & relaxing, working on computer, standing still, eating or drinking, watching TV, reading, running, bicycling, stretching, strength-training, scrubbing,

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vacuuming, folding laundry, lying down & relaxing, brushing teeth, climbing stairs, riding elevator and riding escalator, by using Decision Table, Instance-based learning (IBL), C4.5 and Naive Bayes algorithms [26]. Similarly, researchers identified 12 activities using 3 sensor boards [3]. Researchers identified 3 activities i.e., walking, climbing stairs and descending stairs using 9 tilt switches, by using K-means clustering and brute force algorithms; these sensors were worn just above the right knee [4]. Researchers also identified a few physical activities and strength-training techniques using a 3D accelerometer sensor [9][20][21].

Researchers also have identified different swimming styles by using wearable devices [22][23][24][25].

In our work, we want to develop a single system for recognizing few physical training exercises (i.e., using elliptical trainer, butterfly, bench-press and pull down) and different swimming styles (i.e., dolphin, back-stroke, breast-stroke and free-style).

Physical training exercises are already identified by using a 3D accelerometer [21], but we found following drawbacks:

- Data were not preprocessed before applying machine learning algorithms.
- Only two machine learning algorithms were used.
- It is stated that "For every user, the system needs to be trained with the sensor data so that it would be able to predict physical training exercises using the axivity device" [21].

In this work, we want to pre-process our data before applying any machine learning algorithms. Additionally, we want to use Neural networks [26] because it is known for pattern recognition. We also want to develop a generic system for both physical training activities and swimming styles.

III. Hypothesis and Research Question

The acceleration measured by a 3 axis accelerometer (X,Y,Z) at a specific point (upper-arm), indicates which activity a person is performing (using elliptical trainer, butterfly, bench-press, pull down, dolphin, back-stroke, breast-stroke and free-style), by using J48 [26], AODE [26] and Neural Networks [26].

In this paper, we investigate the practical aspects of creating an automatic, personal activity recognition system. Through our experiments, we want to find the answer of the following question: Is it possible to identify which activity the person is performing (using elliptical trainer, butterfly, bench-press, pull down, dolphin, back-stroke, breast-stroke and free-style) by using a 3D wearable accelerometer sensor on participants' arm?

IV. Experimental Methodology

We used AX3 data logger [1] in order to identify physical activities which is also a water proof device (as shown in Figure: 1).

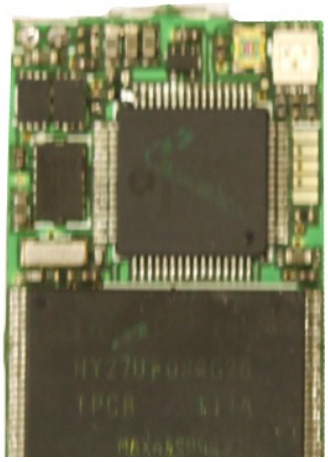

Figure 1: Axivity device

It was worn on the participants' arm and they wore it on the right hands' upper arm (as shown in Figure: 2).

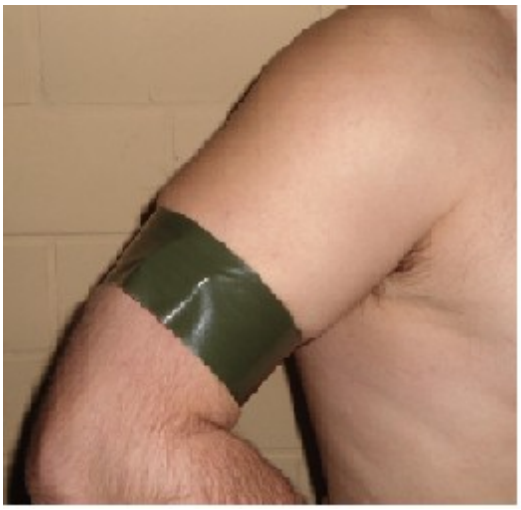

Figure 2: Location for axivity device

The AX3 data logger contains 3-axis of accelerometer with flash memory and clock. This device is small and easy to use, its dimensions are 6x21.5x31.5 mm and its weight is 9 grams. The device comes with pre-installed software with the possibility to configure its settings. For example, we can configure sample rate, gravity, etc. It continuously logs contextual information (time; hh:mm:ss and axis; X, Y, Z) to its internal memory. We can also set the duration for logging this information. There is also a possibility to export the logged data from the device to a computer in comma-separated values (CSV) format.

We implemented an application for 'Pocket PC', where we can state the starting and ending time for each physical activity during experiments. This application generates text files with this information for each physical activity for training data. It also stores the participants' personal

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information i.e., age, gender, height, and weight. We implemented another application in Java for analysis. This application requires two input files: time stamp for physical activities from 'Pocket PC', as well as the CSV file from the axivity device. Firstly, it filters needed data from the CSV file based on the time stamp from the files from the 'Pocket PC for each physical activity and generates training data files in ARFF format. Later, it pre processes the data (which is described below) and then we applied machine learning algorithms (J48, AODE and Neural Networks) on training data in order to get results from all mentioned algorithms (as shown in Figure 3).

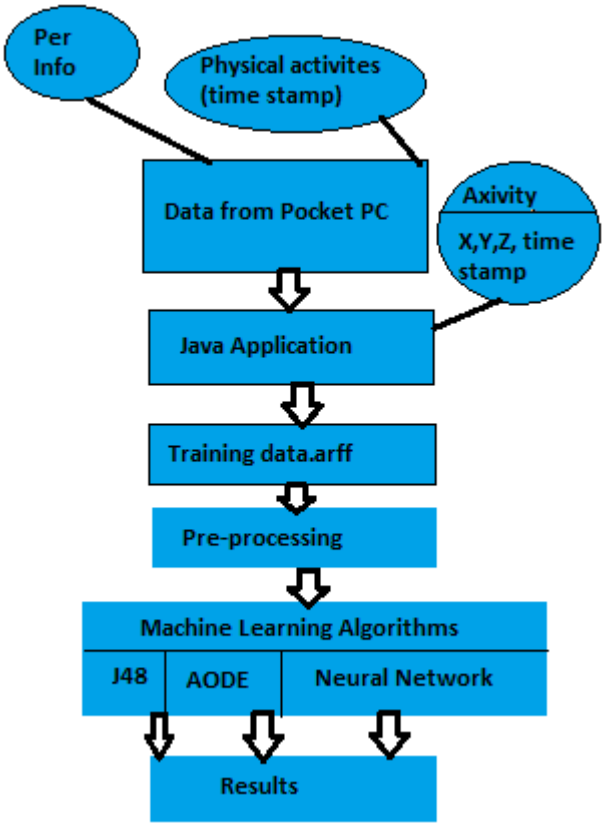

Figure 3: Architecture

A. Data collection from Axivity device

We conducted two user studies in order to prove our hypothesis. One was for identifying physical training exercises and other one was for identifying different swimming styles.

For identifying physical training exercises, we recruited 14 participants (9 males, 5 females) for our experiment setup as shown in Figure 3. The range of participants' age was from 20 to 41 (mean 29.14, SD 10.11) and ranged in BMI (body mass index) [10] from 19.6 to 27.8 (mean 23.03, SD 2.39). They performed each physical training exercises (using elliptical trainer, butterfly, bench-press and pull down) for a minute.

For identifying different swimming styles, we recruited 6 participants (5 males, 1 female) for our experiment setup as shown in Figure 3. The range of participants' age was from 19 to 42 (mean 29.17, SD 19.58) and ranged in BMI (body mass index) [10] from 19 to 24.8 (mean 21.48, SD 2.16). They were required to swim 30 meters in each swimming style (dolphin, back-stroke, breast-stroke and free-style). Our participants had different swimming levels, some of them were beginners and some of them were expert in swimming. Some participants were not able to swim in dolphin style.

In order to attach this device on the participants' back, we used sticky tape which was directly placed on the skin. We logged continuous data with 8G and the sample rate was 100 Hz. At the end, we collected data from 20 participants out of both studies (physical exercise activities and swimming styles).

B. Ground truth

Participants' were continuously observed during experiments. An observer was stating starting/ending time of each activity.

C. Pre-processing

Each window represents a data of 5 seconds and it contains correlation of (X, Y), correlation of (Y, X), correlation of (Z, X), average of X, average of Y and average of Z.

D. Classifications

The 10-fold cross-validation is used to evaluate the J48, AODE and Neural networks (Multilayer perceptron) models. We used WEKA toolkit [17] for evaluating our results.

V. EVALUATION

Our results (Table 1) show that "Using elliptical trainer" activity was predicted with an accuracy of 90.64% by the J48. J48 was also able to predict other activities with better accuracy than other classifiers except "Back-stroke" and "Breast-stroke" activities. "Back-stroke" activity was better recognized by AODE classifier and "Breast-stroke" activity was better recognized by Neural Networks. "Free-style" was recognized by all classifiers with same accuracy.

TABLE I. COMPARISON WITH OTHER CLASSIFIERS

	J48	**AODE**	**Neural networks**
Using elliptical trainer	90.64%	68.98%	89.84%

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Butterfly	74.42%	47.09%	66.86%
Pull down	83.15%	79.35%	76.63%
Bench-press	77.66%	45.74%	68.09%
Dolphin	80.00%	80.00	26.67%
Back-stroke	64.52%	70.37%	68.97%
Breast-stroke	77.78%	59.26%	81.48%
Free-style	52.38%	52.38%	52.38%

VI. Conclusion and Future Work

Our system is able to recognize a high percentage of the aforementioned activities with the help of the J48 (decision tree) classifier. These preliminary results have shown that one 3D accelerometer sensor may be enough for identifying a few physical activities (using elliptical trainer, butterfly, bench-press, pull down, dolphin, back-stroke, breast-stroke and free-style). We may get different results when we use another 40 or more samples, this prototype is only a "proof of concept" and our results show that a single 3D accelerometer sensor can identify the above mentioned physical activities independent of BMI (body mass index) and age group. The accelerometer sensor has to be fixed properly on the participants' backbone in order to predict the participants' activities successfully. We will put the accelerometer sensor on other parts of the body in order to identify some other physical activities and we will use it for online machine learning.

Acknowledgment

This research was funded by USEFIL [27].

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Towards unified tooling for easing the qualification of medical normed environments

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***Abstract*—Medical confined environments are characterized by a very stringent set of standards and regulations, depending on a wide range of parameters. These are very difficult to handle because of the lack of appropriate tools to qualify before use, monitor during use and audit after use. Providing these tools requires to tackle the complexity of gathering all the different elements of the environment profile (building topology, standards and rules, instrumentation) in a single model which could be statically validated and dynamically checked against events. This article both focuses on introducing the context of medical confined environment regulation and issues faced when trying to design and implement qualification and monitoring tools, and on presenting the approach and work in progress.**

***Index Terms*—Requirements Engineering; Model-Driven Engineering; Medical confined environment; Qualification**

I. Context

Confined environments can be defined as space-limited areas, hosting a product or process, in which all uncontrolled transfers between the inside and the outside world are forbidden. In some cases, motivation is to protect the process against outside contaminations (such as in surgery). In other cases, it is much more to protect the outside against contaminations by the process itself (such as in virology).

Confined environment characteristics (such as use, manufacturing, high attendance, location…) imply strong constraints and, therefore are ruled by several design methods and use guides. These regulations lead to the definition of "normative layouts", consisting in a set of standards a given environment has to comply with. Moreover, the norms are not all opposable, some are only good practice or advice (such as the World Health Organization (WHO) documents [1]).

To illustrate the needs and issues related to our work, we will use a simplified "Centralized Reconstitution of Cytotoxic Drugs Unit (CRCDU)" (Fig. 1) all along the article. In these environments, users are expected to prepare drugs, under chemical hoods in a dedicated room, which will be used for antineoplastic treatments. Here, confinement protects preparations from external contamination by a gradual asepsis [2]. *Inter alia*, it consists in several pressure stages as well as by the rooms' conformance to several (and gradual) ISO levels (ISO 14644-1 [3] standard defines the allowed concentration of particles of various sizes). In France, depending on the context of implementation, a different set of laws, best practices [4]–[6] and norms [3], [7], [8] regulate these units.

The first room is a clearance room, remaining in a particular pressure level in order to protect itself from outdoor atmosphere (whose pressure is considered as a reference). An airlock allows users to dress, and thus acts as a first decontamination stage. Finally, users reach the preparation room with the highest pressure level and the lowest ISO class.

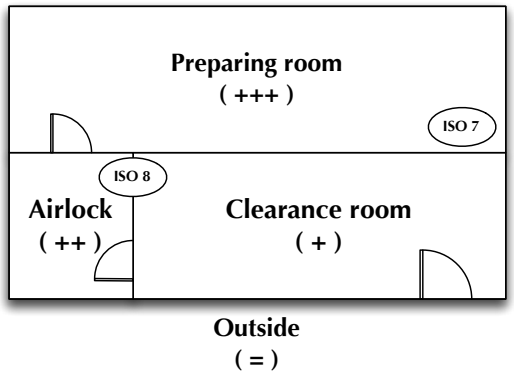

Figure 1. Illustration case: simplified CRCDU

II. Motivations and issues

Human and financial risks related to the design, or the use, of noncompliant environments lead to the need for qualification of such environments before commissioning, but also for their monitoring and auditing after the operation. To support this assertion, it is enlightening to remember that in France, there are more deaths each year by nosocomial infections than

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by road accidents. There is a strong need for an integrated toolset, presented in Fig. 2, operating cooperatively all along the confined environment lifecycle (design, commissioning and use).

To summarize:

- upstream of any project checking (0), an analysis is required to proceed with the next two steps ;
- for each project:
  - during the design (1), it should be possible to qualify a confined environment by using only its technical data, to determinate, *a priori*, its conformance ;
  - during the usage (2), the need is to trace usage in order to follow the evolution of the confined environment and to keep its history for audit purposes.

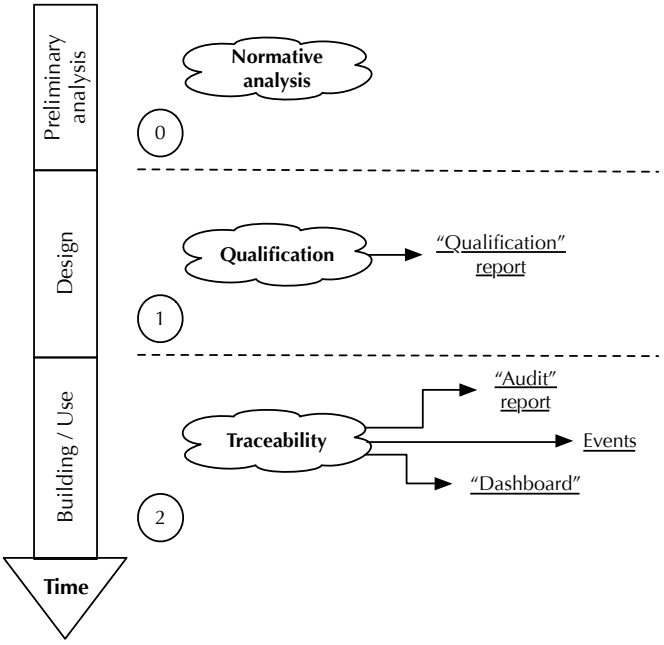

Figure 2. Required process

This section details the required features.

A. Analysis (0)

This is the entry point of the toolset, its preamble, the basis of all the process. The objective is to constitute the normative layout of a kind of medical confined environment and process it to extract the elements required by the qualification (II-B) and the monitoring (II-C). This operation will be done according to the type of environment or according to the "version" of the normative layout, evolving in the same manner.

In the chosen example, it is the analysis of the documents composing the normative layout of a CRCDCU (among which the documents [3]–[8]).

B. Qualification (1)

During the design phase (next section), it should be possible to qualify a confined environment by using only its technical data, to determinate, *a priori*, its conformance with its targeted usage. It is a typical case of Requirements Engineering (RE) [9]. To simplify, it is an engineering domain, targeting the checking of a product against its requirements ; all the process is considered from the requirements elicitation up to the product conformity checking. In this step, the objective is to produce a "qualification" report, which will provide the decision aids allowing to enhance and maximize the conformity of the project with its normative layout.

In our use case, considering the foreseen use of the unit, rooms (size, volume, relative layout...) and their instrumentation (sensors, actuators, external systems...), the qualification would consist in checking all required systems are present ("Heating, Ventilation and Air-Conditioning (HVAC)", access control...) and that they are properly configured.

C. Monitoring and traceability (2)

After commissioning, it is necessary to trace usage in order to follow the evolution of the confined environment and to keep its history for audit purposes. Monitoring then aims at delivering a "specialist-oriented" feedback, giving a clear and cohesive view of running operations to various users rather than trying to automate a complete normative usage analysis. Thus, a customizable "dashboard", displaying only the relevant information, could perfectly embody this feature.

In our example, this could consist in recording the evolution of the pressure in the various rooms, in checking that airlock system is properly running as air velocity and throughput are compliant to requirements...

III. Approach and Work in Progress

Our work focuses on the design of a unified process (called the "methology" in this section) to answer the need presented in Fig. 2. We drew the sketch of the process architecture in a previous paper [10] and conduced additional research to refine its operating and set its technical details. Figure 3 presents this enhanced version, based on model design and transformation, for which we are addressing steps 0 to 2.

The qualification tool (0 & 1) has to take some abstract representations as inputs, in other words, models of both technical data and applying standards. This leads to tackle an RE problem using "Model-Driven Engineering (MDE) [11]" ; an approach called "Model-Driven Requirements Engineering (MoDRE)". The realization of these models could be unified in a megamodel [12], interconnecting the metamodels of each component with the required weaving models and so on. As most of the time the normative layout also induces alternatives that lead to several solutions (i.e. building and instrumentation that conforms to it), a notion of "prominence" in the qualification process consequently has to be taken into account. These models (and the linked constraints) represent the abstract syntax and semantic of our modeling language for confined medical environments, the last point is the concrete syntax. As a reminder, this is the syntax (graphic or textual) that the user will manipulate and use to model their project. The challenge is to design metamodels flexible enough to support

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the whole targeted domain while providing a framework strict enough to automate checking and data extraction operations. This means a trade-off between the ability to easily model the target and the expressivity required for the transformations generating the "qualification" report and the next step.

About the applied profile (2), its presence is required by the need to reengineer "high-level" model of the targeted environment and its "normative layout". Indeed, the environment profile used during qualification is too abstract to be used directly by the monitoring platform. A strict rule such as "two doors of an airlock cannot be opened simultaneously" has little concrete links within the "computer world": what is an airlock? What is a door? How should its state be read? The model produced by the user to assess their project should partially or completely be automatically reified in an easily manageable version by the monitoring platform. In our example (Fig. 1), this could lead to explicit constraint definitions like "P1 pressure sensor value should always be greater than P2 one", "opening indicators cannot be active at the same time"... Obviously, required information should be introduced in models, to identify P1, P2 and opening indicators. Profile generation is a requirements reengineering problem, consisting in automatically extracting relevant parameters from the abstract profile in order to configure the monitoring platform.

Concerning the traceability platform (3), among the complete set of exploitation constraints, the most important are: the qualification as "Medical Device" [13] ; the data use in legal cases which requires integrity-guaranteed data [14] ; the support of all the legacy systems already deployed in the targeted confined environment and the adaptability to a profile and an environment which will evolve over time. Here, the challenge is thus as much in the design of the tools themselves as in this specific context of deployment.

We are currently setting up the methodology on real cases. We are working on the analysis step (0). The design of the metamodels enabling to model the building and its instrumentation was the first step and now, we are handling the normative processing. The production of the normative layout and its analysis is a manual process, leading to extract a relevant megamodel which will be the core behind the modeling workshop. It is specialist-oriented work, requiring great knowledge of the concerned domain, provided by Nocosium. As stated in the previous section, we do not aim at a very sharpened concrete syntax and we work more on the methodology than on the user experience. The concrete syntax (presented in the Section II-B) is more an "engineering" problem which would be better tackled later by engineers because there are no real research locks. These further works should investigate the current business processes and determine how to integrate the modeling part in their workflow.

Our first application scenario is the CRCDU presented all along this article. This work enables us to achieve a kind of typology of the normative constraints. Indeed, we can discern several types of constraints depending on the verifications required to conform with. For example, the constraints based on the presence of a specific element (e.g. pressure sensor to ensure pressure monitoring) differ from constraints based on the configuration of a sensor (e.g. frequency of the pressure monitoring) or from functioning constraints (e.g. the calibration of pressure sensors). The means to check them are different.

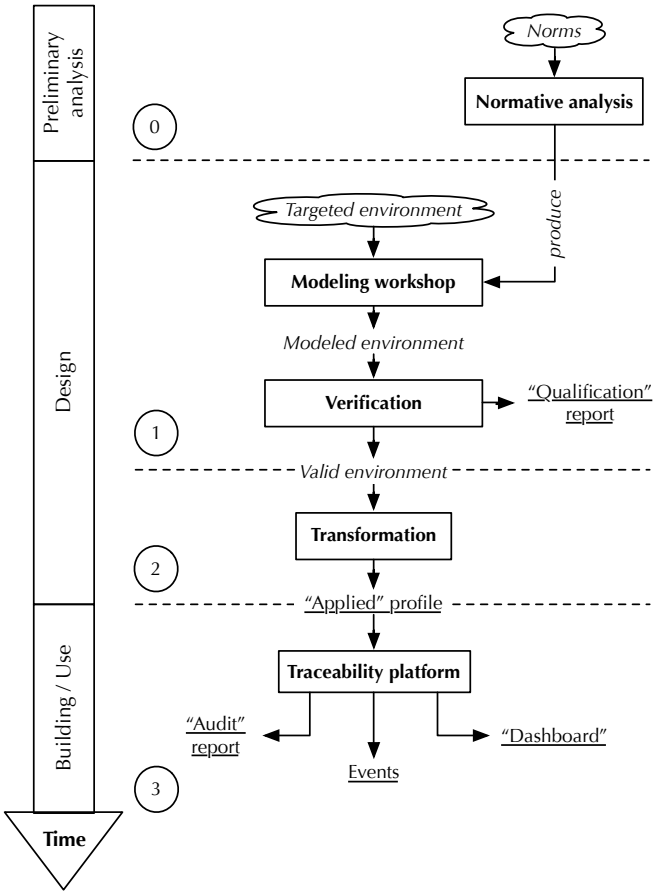

Figure 3. Proposed approach

So, we are currently analyzing the CRCDU "normative layout". For each norm, we classify the constraints and report them into the megamodel or later in the methodology. The produced metamodels are Nocosium's property and will not be presented in this publication.

IV. Discussion

Requirements engineering is a transversal thematic spanning over several scientific fields, not necessarily technical, like in contributions examining the adequacy of a process of requirement validation with a company's workflow. In this thesis, we adopt a fully technical stance and we assess its feasibility, efficiency and limits. Hence, we have to compare our contribution to the other technical approaches for requirement engineering.

The contribution presented in this paper is downstream of typical IT approaches for requirements engineering, like the "Knowledge Acquisition in automated Specification (KAOS)" method [15]. These works aim at identifying the inconsistencies and the conflicts in the targeted requirements for a given project.

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This is not our case: we adopt the point of view of the "maitrise d'ouvrage" for which the normative layout cannot be altered. We aim at checking the project against the normative layout. In the same search area, we can also quote the PhD work of Nicolas Sannier [16], on the coherency analysis and the conflict detection, between the various versions of the same norm. Once more, this work is upstream our own objectives.

We can also quote the PhD thesis of Panesar-Walawege [17] aiming at analyzing the conformity of safety-critical systems with the relevant IEC norm, by the UML modeling of the norm to extract the list and calendar of the artefacts to produce. However, we handle different (although complementary) aspects. We will not check if the "maitrise d'ouvrage" produces the required elements but if the project is conform. To put it shortly, it is almost, an opposition between syntactic and semantic analysis.

To conclude, there is not much research on global approaches of requirements engineering (from conception to audit) targeting normed environments.

V. Conclusion

Confined environments are controlled working zones where all unmanaged transfers between the inside and the outside are forbidden. We intend to define a methodology to qualify the normative conformity of an environment, then checking the durability of such compliance over time. The first steps of this process will be validated at the end of the engaged PhD thesis.

Environment qualification should be done only using its technical data. We suggest to address this requirements engineering problem by allowing the definition of an integrated environment profile merging three components: "building", "instrumentation" and "requirements".

Environment monitoring should allow to trace use and to give immediate feedback to practitioners via a dashboard, but also to collect data for further audits. We propose to address monitoring platform implementation issues by the use of service-oriented architectures, particularly to sustain environment changes (building, requirements, instrumentation).

There is not much research on global approaches of requirements engineering (from conception to audit) targeting normed environments. It is this lack that we aim at tackling and in this thesis we validate the first steps of our proposition.

Acknowledgment

This work is funded by the Nocosium company under a French "Convention Industrielle de Formation par la REcherche (CIFRE)" Doctoral Convention.

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Emergency Web App for Accessing the Medical Emergency Services

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***Abstract*-Nowadays, accessing emergency services and customer healthcare, in Spain, is done only by traditional phone calls to the number 061. In order to facilitate interaction between the emergency users and the emergency service system, we are improving and expanding new channels of personal communication. Given that the use of smart mobile devices is widespread in our society, we are developing a mobile application for emergency management, providing the same assistance as phone calls and adding some brand new features. We have developed requirements design and a functional specification of our new mobile application aimed at improving user interaction with the traditional emergency systems. The functionalities of the Web application are focused on providing a direct communication service, complete and effective, allowing quick and accurate intervention of the emergency services. Our purpose is to define a platform fully accessible to all users, regardless of their language and/or technological knowledge. Thus, the focus of this paper is mainly devoted to explain how to extend traditional applications based on emergency phone calls, to modern mobile applications considering not only web technologies, but also social networking behavior.**

Keywords-Healthcare Emergency System; User Interaction; Mobile Devices; Web Applications.

I. INTRODUCTION

Before the decision of the European Union (EU), in 1991, to have a single phone number for European emergency calls, accessing healthcare emergencies and medical urgencies is Spain was performed by dialing 061. The EU decision, legislated in Directive 91/396/EEC of the Council of the International Association of Emergency Managers (IAEM) Spain from July 29, 1991, defined the dialing number 112 for these European emergency calls and added, in cases where it is considered appropriate, this number will be introduced in parallel with any other emergency number that existed before.

The Medical Emergency Services (SEMs for its acronym in Spain) belong to any public health system integrally. Its main function is to provide medical care in all emergency situations, including disasters. Medical emergencies have two main assistance scopes: hospitable, through emergency services of the hospitals; and extra-hospitable, which can integrate different resources and types of assistance depending on the health model of the country in terms of integration or not integration of specialized primary assistance into a single health service and the type of the provision of services.

Therefore, extra-hospitable emergency health services are defined like a functional organization that performs a set of sequential human and material activities with fixed and mobile devices, with appropriate resources, coordinated, initiated from the moment in which the medical emergency is found. Thus, after consideration of the needs, it is assigned a response without mobilizing any resource or moves their devices to act in situ, perform medical transport if necessary and transfer the patient to the appropriate facility for definitive treatment.

The protocol of Emergencies Service and Medical Emergencies indicates that the incident or accident and the corresponding emergency assistance are done in a different intervention chain, as it is shown in Figure 1. Thus, the first people to intervene may be the patient, witness or designated first responders (firemen, police). This is the weakest link, as a few Spanish citizens are trained in first aid. Neither the personal of some services and institutions which expected higher occurrence of people or a greater probability of emergency are trained in these first aids. However, this reality increases the results in terms of survival, as witnesses and first involved people apply basic life support and defibrillation, while the first health equipment arrives, remain essential for the survival in cardiac arrest cases. The second link is a call initiation done by the first involved people through 112 or 061, and received by the Coordination Center, which serves the emergency phone, and according to its characteristics or severity, it is decided to follow action: resolution of the phone call, resource mobilization, or referral of the patient on their own to a given health center. So, as third link, the Coordination Center has the quest to obtain the appropriate resources for appropriate patients in appropriate timeframes.

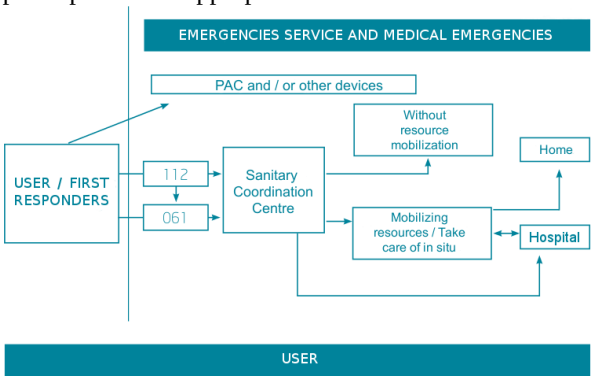

Fig. 1 Emergency Service Flowchart [1]

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Early care services, transportation services and hospital emergency are not the scope of this paper. Within this response chain, the appropriate Emergency Services chain begins with the receipt to the call at the Coordination Center for following coordination of no health emergency devices.

In the specific area of the Autonomous Community of the Balearic Islands, where our university is also located, SAMU 061 (Emergency Medical Service 061) is a public Emergency Medical Service under the Health Service of the Balearic Islands that has the responsibility for healthcare emergencies and outpatient emergency in the territory of the islands [2]. Nowadays, the user who needs to access SAMU services should make a phone call by dialing 061 (link 2), based on the Protocol of Emergencies Service and Medical Emergencies described before, which will be run by an operator (link 3) who will manage the incidence and will organize the needed resources based on the information described by the user, as detailed above.

Such an approach would generate a list of services focused on assessing and responding to any emergency; thus, our new *Emergency Web Application* includes, among other features, the following functions: collecting user's personal data, emergency registration through a set of questions and emergency registration in state of panic, with the aim to improve the first customer assistance. In terms of interactivity, it will also be essential to make a detailed study of user in with the platform. Our purpose is to define a platform fully accessible to all users, regardless of their language and/or technological knowledge.

The paper is structured as follows: in Section II, research and implemented development related to this work is depicted. In Section III, the current technological environment of SAMU for the control and management of emergencies is overviewed. Section IV will present the solution we designed to provide new channels of communication between the user and SAMU. We conclude with some final comments and open problems in Section V and final observations in Section VI.

II. Related Work

Several functionalities have been studied and designed to improve access to healthcare emergency assistance and medical emergencies, so that they generate social benefit of these services and content, in particular to improve the interaction between the healthcare emergency system and their users. In fact, Alcalde [3] already anticipated the trend of access not only by telephone, but also through social networking, IP telephony, messaging and mobile applications, as well as video and image distribution. The authors propose new VoIP phone technologies and flexible architecture between different emergency centers.

The Fire Department at San Ramon Valley (California, U.S.A.) has developed an application that offers continued connection with 911 emergencies service by mobile phone [4]. The application takes advantage of their phone location, so that users that indicated they have been trained in Cardiopulmonary Resuscitation (CPR) and would be willing to help in an emergency can be messaged to do it. Therefore, the 911 dispatch center receiving a call for an emergency that is occurring near the trained user, will send a notification telling his/her help is needed in the surrounding area.

Other researchers from University of Texas [5] reveal next-generation emergency response technology related to mobile phones. Specifically, the smartphones can be placed directly on the chest to monitor breathing, heart rate, blood pressure and transmit this information directly to the operator of the call.

Besides, previous introduction to the study of user interaction is explained by Gómez and Juiz [6]; we explained the importance of adding a new channel of communication between emergency services and the user. Similar to the Fire Department App, the application communicates with the user via the mobile device (Fire App by notifications, our app by chat). Our application also intends to use a system similar to his personal data record. On the contrary, they have already integrated the location by GPS; however we will incorporate it in the future.

These are only a few examples from an increasing application list [7] that could include “SOS First Aid”, “PocketCPR”, “iRescue”, among others, all of them taking advantage of social impact of mobile devices and trying to improve healthcare.

III. Technological Scope: The SENECA Platform

SAMU061 uses the product for emergency management services developed by Telefónica [8], known as SENECA platform.

Telefónica is an integrated operator of telecommunications, leader in Spain. Its activity is basically focused on fixed and mobile telephony business. However, in terms of health, Telefónica has been betting strongly for the development of innovative services in eHealth and telecare areas, especially for the elderly and patients with chronic diseases. It is important to add that Telefónica is a European Emergency Number Association (EENA) Advisory Board Member. EENA is a Brussels-based NGO set up in 1999 dedicated to promoting high-quality emergency services reached by the number 112 throughout the EU. So, Telefónica has registered its SENECA platform in EENA, supporting, giving and sharing eHealth solutions.

Specifically, SENECA is suite that includes four operational products available in the *SENECA Emergency Suite* (SES). SAMU 061 works through the second one, i.e. SENECA Health. The technological infrastructure of the whole SENECA platform is based on market standards and industry. They integrate in the process of implementation of Emergency Centers helping their customers in issues like operations analysis based on service needs and the current situation, definition and planning of change management activities, cooperation with the agencies, in an effort to stipulate protocol and methodology and management of the complete incident cycle, taking into account citizens, management operatives or intervention.

SENECA Platform includes a client-server architecture for Local Area Network (LAN) used by the management database server processes to communicate with incidences users. The

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operating environment of the SENECA shown in Figure 2 is based, in general terms, on the sharing of a common database between communications processes, management (CAD), geographic information systems (GIS) and its corresponding exploitation.

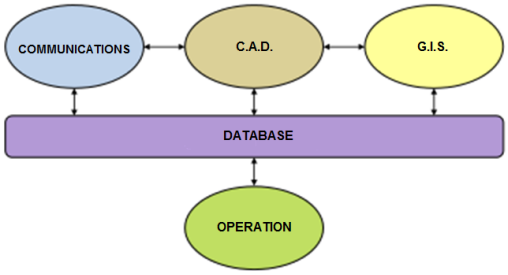

Fig. 2 SENECA Platform Data Base [9]

In terms of system, SENECA provides an integration of communications services and incident management based on a design addressed to the user. It provides an operator interface that clearly presents all necessary information and simplifying the decision-making for trained operators at call centers.

A. General Description

The SENECA emergency platform is comprised of a series of functional modules which can be divided into two groups:

Core Services [9]: Among its features are the following: voice integration, mapping information system, demand management (attention, location, dispatch, monitoring), basic alarm system, asynchronous event distribution bus, and storage of configuration data. The Core is also comprised of the following modules:

- Data Base: SENECA Data Base is based in the Oracle 10G R2 Data Base Management System. The data base stores information about SENECA Platform configuration, Business Data, Mapping Information, and system register messages.
- PABX: Private Automatic Branch Exchange is the voice commutation central used by the telephony system. It is possible to integrate itself with different manufacturers, included those based in VoIP technology.
- ACD: Automatic Call Distributor is a device that automatically distributes calls that access the PABX among agents.
- CTI: Computer Telephony Integration intended for interaction between a telephone call and actions taken by a computer system in an integrated and coordinated way.

Client modules: Contain functionalities of management and dispatching, where one can find the platform modules residing in the operating positions thereof. These are the graphic interface modules, which provide the functionality to users, and background modules serving the core.

- COMS: Communication Window that provides communication services of the operating station platform while maintaining control of telephony, phonebook, radios management, and recorders.
- GIS–Maps: Cartographic Viewer and positioning.
- CADM: Care and Dispatch Window, incidents control, authority and resources.
- COSE: Tracking Window of several information such as call letters, files, resources, information search, operator-definable filters, refreshment in real-time through the distribution bus events, among others.

B. Additional Modules

SENECA Platform has several additional modules related to Core Services and Client modules. Although they are not strictly necessary for its use in relation to management emergencies, it does offer a number of features and benefits to support the management mentioned. Thus, one can find:

- Mobile location: responsible for determining the position of the mobile phone calling to the emergency center that is managed and stored by the platform.
- Dispatching and integration of emergency calls made by deaf people is also provided.
- Integration with radio communication solutions.

C. Operating Environment

SENECA Platform is mainly aimed at emergency and medical emergencies centers, among which are 112 Coordination Centers, Health Care and Emergency Medical Services, Fire Corps and Rescue Services, Police Forces and Security Services and Civil Protection.

Telefónica leads the Spanish Emergency Centers, specifically 112 Coordination Centers in nine communities, as well as Health Care Services in six of them. In terms of safety, National Policy Force belonging to Ministry of the Interior, and Civil Guard are also lead.

IV. EMERGENCY WEB APP

To improve the interaction between the user and the emergency center, we integrate a new communication channel taking advantage of the increased use of mobile devices accessing to the Internet. Our proposed solution consists on a cross-platform web application, easily adaptable to any mobile, and multi-language, making it accessible to all users, regardless of their technical knowledge and/or language. This last feature is really a requirement in several territories in Spain, e.g. the Balearic Islands, due to the huge number of foreign visitors per year. According to the Tourism Strategy Institute (INESTUR), in the Balearic Islands on 2009, shown in Table 1, more than 11.5 million tourists visited the islands through aerial and maritime ways, which means a special careful interest in the diversity of the idiom.

TABLE I. FOREIGN VISITORS PER YEAR

	Foreign	Spanish	Total
Aerial way	8.917.460	2.311.535	11.228.995
Maritime way	62.526	317.641	380.167
Total Balearic Islands	8.979.986	2.629.176	11.609.162

Thus, we have prioritized the multi-language feature and designed our application such that, once started, the application requests the language in which you want to be attended to.

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Following, there is a form to fill a small number of fields about the user's personal data such as your name, address, telephone number, and more. This is followed by triage questionnaire to determine the type of emergency that the user suffers. Finally, the user gets in touch with an operator through chat system, or if the severity level requires it, it starts communicating via traditional phone call.

In technological terms, the mobile web application is developed in two main blocks: Graphical User Interface (GUI) Module and SENECA Integration Module.

A. GUI Module

In the Web Application GUI, the user interaction has been developed by Sencha Architect [10], the HTML5 visual app builder. Sencha has a code editor that guides to build any application using Model View Controller (MVC), thus both components that represent information and components that interact with user are easily identifiable, improving the development and subsequent maintenance.

Sencha Architect is mainly based on JavaScript language, and the visual part is edited with HTML5 and Cascading Style Sheets (CSS) to make it more attractive. One might add that configuration of visualization files, event files or data model files are structured following the JSON (JavaScript Object Notation) [11] syntax. However, developers may use their own IDE because there are no file dependencies, and Architect produces regular JavaScript files that can be edited with any IDE.

The GUI Module is structured according to MVC. In the Models information, the language model, the user data model and the triage model with relevant variables are included. To access these latest models, Sencha configuration Stores are accessed through a Proxy Ajax that contains the structure of the models described in Json files. In Views information, the application *Emergency Web App* is divided in several panels. The main TabPanel welcomes the user to the application and the language requested by a Select field. With the Tab Bar, it is possible to change to the form which asks for data to the user. Once this information is sent via Submit button, the user accesses the second form, where triage is performed based on the emergency class. After that, the application gives access to chat. The controller section is made from SENECA Integration Module.

B. SENECA Integration Module

We have used Service Oriented Architecture (SOA) [12] to establish the communication between our Web App and SENECA Emergency system. SOA is a software design and software architecture design pattern based on discrete pieces of software providing application functionality as services to other applications. To communicate, these services are based on a formal definition with platform and programming language independence. The definition of the interface [12] encapsulates the characteristics of an implementation, making it independent of the manufacturer, the programming language or the technology development. With this architecture, it is intended that developed software components are very reusable because the interface is defined according to a standard, so a C# service could be used by a Java application. In this sense, Mascaró defines SOA as a Super-abstraction [13].

One of the greatest economic and technological problems of the applications is scalability, either the ability to react and adapt without losing quality, or to be prepared to get bigger without losing quality in the offered services. SOA ensures the scalability thanks to its easy assembly of several systems which facilitates the interaction between different own systems or third parties. SOA is like a producer-consumer system based in services and messages, where there is almost a server provider, a consumer and a service repository.

As one can see in Figure 3, the service is a single and independent logical piece of a business process, integrated inside of the service, and interacts with the external world using an interface. Each service can have its own logic business rules easily accessible and modifiable at any time. The server provider starts when someone invokes the service. It drives the business logic and sends a response if it is necessary. Therefore, the service consumer sends a message to the provider to access the service.

SOA lets us develope global systems that interact with each individual business system. In fact, each system is a Web Service integrated in the WWW. In this case, SENECA Telefónica has created the Global System and the Emergency Web App is an individual system that interacts with Global, both being Web Services.

Web Services is a technology that uses a set of protocols and standards used for exchanging data between applications. Different software applications developed in different programming languages and executed on any platform, can use web services to exchange data. Interoperability is achieved by adopting open standards. OASIS (Organization for the Advancement of Structured Information Standards) and W3C (World Wide Web Consortium) organizations are the responsible committees for the Web Services architecture and regulation. Thus, Web services allow software and services from different companies located in different geographic locations can be easily combined to provide integrated services. Thanks to the great independence between the application that uses the Web Service and the service itself, changes in one of them over time should not affect the other, as long as the established agreements are maintained in the protocol.

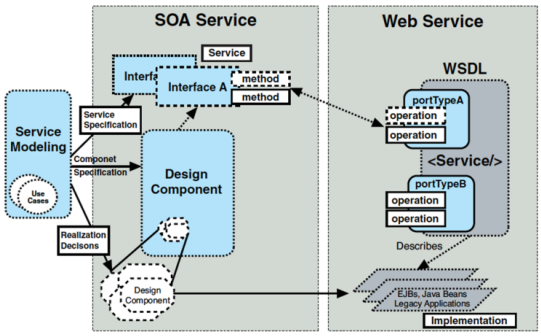

Fig. 3 SOA & Web Services [13]

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The information exchanged between services is performed using messages. In our case the standard protocol to send these messages is SOAP (Simple Object Access Protocol) and the description format is WSDL (Web Services Description Language) format.

SOAP [14] is an XML based protocol for exchanging structured information in the implementation of Web Services in computer networks. SOAP offers a basic messaging framework upon which web services can be built. This protocol consists of three parts: an envelope, which defines what the message contains and how to process it, a set of encoding rules for expressing instances of data types, and a convention for representing procedure calls and responses. SOAP protocol has three main features: extensibility, neutrality, as SOAP can be used over any transport protocol, such as HTML, SMTP, TCP or JMS, and independency, because SOAP supports any programming model.

WSDL is an XML [15] which is used for describing Web services. WSDL describes how communication, i.e. the requirements of the protocol and message formats required to interact with the services listed in its catalog. Operations and messages supported are described abstractly and linked to concrete network protocol and message format.

The client program (our *Emergency Web App*) that connects to the Global Web service, can read the WSDL to determine what functions are available on the server. The special data types are included in the WSDL file in the form of XML Schema. The client uses SOAP to make the call to one of the functions listed in the WSDL. The WSDL gives us a description of a web service. Specifies the abstract interface through which a customer can access the service and the details of how to use.

The structure of any WSDL file always contains at least the tags *type* that defines the data type used by the Web Service, *message* for the type of messages, *portType* which includes the type of messages that define a communication, *binding* to see how the Web Service is implemented with SOAP, and *service* that indicates the Web Service location.

In the Emergency App, WSDL is used in several key roles. One of them indicates the logging mode to the Global Web service. The request asks user name and password in the format specified in the WSDL and the response returns the token logged. This information is required to the application, not to the user, to give it access to the Global Web service. By this token, Emergency App can access all functions provided by the Global Web services. The number and language format is also set by a WSDL, as well as the fields required to obtain user data and triage in emergency basis. The token must be included in all of the mentioned functions. When user changes the language, the whole application is reflected in the selected language. Global Web service is responsible for providing access and support to the chat service, once required fields are correctly filled in and sent. Another WSDL-based application closes the session thus releasing the token.

The selected technology to perform this SENECA Integration Module was Java through NetBeans IDE [16]. The integrated development environment has several complements that easily automate the consumer client creation. NetBeans interprets WSDL files; both in local and remote place, getting necessary functions and data types for generate objects and Java classes accessing the consumer server. Automatically generation of code based on WSDL interpretation gives as a result two objects and a service class, among others. Objects represent the requested message and the response message. At the beginning of the object one can see a WSDL fragment in XML according to the expected values. Service class encapsulates the messages, receives and sends it and shares information between those and Java objects. Thus, application is structured in a simple and easy way.

C. GUI Module next to SENECA Integration Module

Module GUI has been easily integrated in SENECA Integration Module on a single IDE, also NetBeans, which generates Web Service client that communicates with the Global Service. As we have mentioned before, Sencha has not any file dependence, so we only had to import this JavaScript files and JSON files that contain the data model. The response of the server, in JSON format, has been processed by a data treatment function, thus GUI Module can represent language and required camps of the questionnaire.

It is not the intention of the authors of this paper to describe the details of the Global Service, in parallel developed by Telefónica Sevilla Development Group. Therefore, the interoperability of both blocks with the SENECA platform is guaranteed regardless of language, platform and configuration.

V. RESULTS

Emergency Web App is a mobile application, even though its name induces confusion. We decided to use HTML5 in the development of this project to be independent of any platform (Android, IOS, WPhone, and Blackberry). We evaluated the use of Google GWT or some derivate (GXT, SmartGWT) that allow traditional Java programming, but the result of the compilation would have been an AJAX web application.

As a second option, we could write HTML5 code directly using some sort of framework or JavaScript framework. At this point, we evaluate two possible ways: jQuery Mobile, compatible with several devices and a powerful visual editor that facilitates development in HTML5; and Sencha Touch 2, developed by the same group as GXT Library, fully oriented to mobile devices.

At this point, we can say that the final choice was to use Sencha Touch 2 for the development of the client. As described above, Sencha has a programming environment, very comfortable and complete, known as Architect. Also, because it is practically based on HTML5, Sencha not only ensures the independence of the mobile device that the user could use, but, in fact, the application is accessible from any web browser. Hence, the final name has been chosen to be *Emergency Web App*.

The final result of the application, in terms of the graphics, has been extremely positive. Being based on JavaScript, integration with Web Service has been direct and without mishaps. In addition, the display emulates any mobile device,

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using a similar complements, whether buttons, bars, selectors and even sliding screen even visible from the web browser.

The left side of Figure 4 shows the running application emulating a web browser on an iPhone. Therein welcomes the application allowing modifying the language from the selector below. It starts in Spanish by default (Telefónica is who provides us the languages). By the bottom menu of the application, one can access the form that the user must complete before allowing access to chat. It lists the required fields to be filled. Once completed, the user does not have to re-fill again. Personal data will be registered for future access to the platform. As one can see in the right side of Figure 4, the sliding screen maintains the same visual effect when performing it with one's finger on a touch screen of the latest mobile. The graphical interface is not bounded to a specific size, but, on the contrary, is adapted to the size of the device that has been executed, so that it keeps its visual appeal whether it is a small mobile device, as if is in a tablet, a laptop or a personal computer.

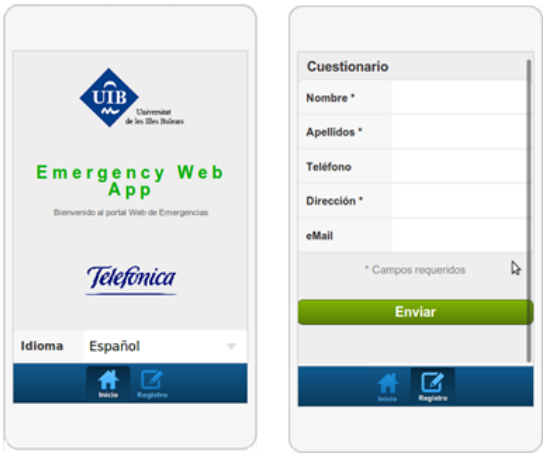

Fig. 4 Welcome to the application [6]

Regarding integration modules with Seneca Platform, creating a Web Server Client was the best option considering parallel work in specific modules would perform with Telefónica Technology Department in Sevilla. Apart from that, this application is an integrated module in the Platform Seneca, an existing service, functional, and for this project, unknown and without needing to know in depth its functionalities. Therefore, we can say that the two features that should meet *Emergency Web App* about multiplatform and multi-language have been successfully achieved.

VI. Conclusion and Future Work

According to the conclusions of the round table "Apps health, are we ready?" [17], it is expected that the number of mobile medical Apps and users that use them, are going to increase exponentially over the next two years. This conclusions stressed the importance of offering creative solutions adapted to the needs of users as patients are willing to pay for Apps "useful and effective" for the benefit of their health. On this basis, it is estimated that, in two years, there will be over 500 million people using medical Apps from mobile.

These expectation figures show the positive reception of the Apps related to medical emergencies by users. Even Telefónica company wishes to initiate and integrate communication through fax, SMS and internet/email and our work is to include this new functionalities in the Emergency Services chain.

The collection and storage of personal information of the caller is a valuable feature because of the possibility of making mistakes due to the poor quality of the call or the caller's state of nervousness or panicking. Through Emergency App, the time for obtaining user data is reduced because he completes the questionnaire in addition to the exact location of the emergency. If it is necessary to access the chat, according to the severity of the emergency determined by the triage, it must have the same priority as common call which ensures real-time attention.

In this paper, we briefly explained our development project in Cátedra Telefónica – UIB, which is not only for business interest based on a new product to offer through SENECA platform, but also for emergency systems, government entities and especially users want ease of access and communication in an area, where time reducing performance, reliability and security are vital in healthcare emergencies and medical emergencies.

VII. Acknowledgment

This research and development project is partially supported by Cátedra Telefónica – UIB: *Digital Health and Sustainable Tourism* and also is partially supported by the Spanish Ministry of Economy and Competitiveness under Grant TIN2011-23889.

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A Quantitative Survey About the Interest of Digital Natives in Second Opinion and Quality/Trust in Online Health Information

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***Abstract*— Growing access to qualified medical information triggers interest and helps patients with their medical conditions, get second opinions, or just share some experience with others. To explore the thoughts of digital natives - what information is accepted and sought after and what information is considered irrelevant or unnecessary - in health information systems, a quantitative survey, from the end users' point of view, with 56 people was conducted. The sample consisted of semi-digital natives aged between 18 and 35. The main results show that a large number of people (78.6%) do an online research after a doctor's consultation. In terms of second opinion, only 33.9% would in principle consider taking a second opinion from online health consulting.**

Keywords-survey; second opinion; user opinion; information system; quality of information.

I. INTRODUCTION

Nowadays, the Internet and modern media are constantly integrated into our daily lives. Web 2.0 and social networking services in general have been experiencing a boost during recent years. 67% of Internet users (n=860) are on Facebook, Pinterest accounts for 15% of Internet users (n=1,802), the percentage of people using Twitter is twice as high as in November 2010 [1]. The primary purpose of these sites ranges from social to professional networking, content production and sharing, to making recommendations and/or location-based services [2]. Sharing information with friends or peers in one's community has seemingly become a societal "norm".

A. Health-related information seeking

The dissemination of health-related data and usage of online support groups in the medical sector, however, remains rather unobtrusive. Survey participants were found to be quite reluctant when it comes to sharing information about their health [3]. Difference in means showed that people who work in a technical field are more likely to share data about a disease (t-test: T=2.071; df=46; p=0.044; 1 - β=0.90). However, users overall do acknowledge benefits by other people's health disclosure. This ambivalence in opinion is mainly attributed to awareness of data security and privacy [3].

B. Social media for health

Only 3.8% of Internet users (n=3,244) reported to use online support groups dealing with similar diagnoses or medical conditions in 2005 [4]. PatientsLikeMe, CureTogether, TuDiabetes, CaringBridge are a few examples of such social networks that provide support by and for patients [5][6]. In fact, a much higher percentage of 58.5% of Internet users explored the Web for information about their health [4]. Other reported uses of social media in healthcare are professional education, patient - doctor communication [2], patient education [7] or even behavior change. The options available are ample, at least in theory. Social media is perceived positively in the health sector [3], especially cancer patients are actively educating themselves [2]. Nonetheless, security aspects, data privacy and access remain crucial in deciding whether or not to disclose health-related information.

On the bright side, investigating and sharing health data paves its way for obtaining, respectively, providing second opinions. A recent report on social media in healthcare revealed that 45% of the participants in a survey (n=1,060 adults altogether) denoted social media to "affect their decisions to seek a second opinion" [5]. Commonly referred to as the process of consulting another person about a matter of interest, the authors add the aspect of looking up health-related information to the definition of second opinions. These are, in general, not limited to a specific field. In here, we focus on second opinions in medicine.

C. Second opinions in healthcare

Underlying motives why people want to get a second opinion are differing. Anxiety disposition, dissatisfaction with the first specialist, desire to have a say in the decision, need for more information, hopes and expectations that the second opinion differs from the first one were revealed as key factors that drove the need to consult a second physician among patients in the Netherlands [8].

A survey among the six US states Florida, Indiana, Louisiana, Missouri, New Hampshire and New York revealed that one out of five patients consulted a second specialist after having visited a doctor the year prior to the study [9]. Perception of being treated badly, affiliation with ethnical groups, among others, were identified as motives to get consults. It was, however, not investigated which disease was the driving force one wanted to get a second opinion on.

Regarding the way these are provided, literature even reports that remote second opinions exist [10]. One example is the Johns Hopkins University [11].

It seems that second opinion is not that widely spread among medical professionals. Hence, the authors' approach is to investigate quality and trust of digital natives in online

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health information as a starting point before such systems get implemented. Presumably, more general topics like recording/administration and processing of data intertwined with social media may have an impact on one's viewpoint regarding second opinion (or how it may be delivered) as well. The authors strongly believe that the perspective of digital natives thereupon may reveal certain trends and help figure out key aspects to consider when building an information system handling second opinion. To the authors' knowledge no such study targeting digital natives has been conducted.

This paper starts with a description of related work (Section II), followed by the methodology used from acquiring to analyzing the data (Section III). Afterwards, the results are presented (Section IV). Section V, then discusses results and contributions. Finally, a conclusion is given in Section VI and some future work is presented.

II. RELATED WORK

Related work dealing with online health information and social media is manifold. The authors are well aware that each diagnosis yields different treatment options. We acknowledge that one's medical history or background also affects the attitude towards second opinion and online health information. However, covering all types of diagnoses is impossible. Also, to the authors' knowledge, publications handling results as they are outlined in such detail in this paper are not existent. Related work presented in this section makes no claim to be complete and aims to look at a broad perspective in online health information and second opinions. Research is divided into three general categories (which have been defined and explained in the introduction): *health-related information seeking*, *social media for health* and *second opinions in healthcare*. Then, our approach in this paper is to build on and to enrich the literature presented here.

A. Health-related information seeking

KHRESMOI, which is a project of the European Union, undertook a survey about health search among the general public [12]. Participants (n=385) answered a questionnaire about their Internet use in relation to health information. Most contributions were recorded in France, Spain, and the USA with 23%, 14%, and 10%. They found that 24% of the sample population look for health-related information at least once a day, whereas the largest focus (68%) was attributed to general information about health issues. The second most important topics for health search were long-term chronic diseases (59%), directly followed by healthy lifestyle and nutrition (50%).

A study among Swiss citizens (n=1,075) found that during the previous 12 months the primary sources for health-related matters were newspapers and magazines (70%), followed by talking to family and friends (47%) [13]. The Internet was consulted by 41% of the respondents. Another question related to the kind of information sought upon in general (n>=4,049). The four top candidates mentioned were treatments, illnesses/diseases, alternative therapeutic approaches and measures for health protection.

On the downside, Gualtieri argues that using "Dr. Google" as one's proxy for a medical first opinion may likely yield serious (negative) consequences [14]. Especially, if people are not adequately equipped with health literacy skills and do not disclose information found on the Internet with their health care provider. Hence, she proposes to strengthen the doctor-patient relationship to possibly reduce non-disclosure and rule out misleading information. This could be done by directing patients to appropriate health websites or specifically asking about a patient's Internet search prior to the appointment.

B. Social media for health

A social network targeting people suffering from amyotrophic lateral sclerosis (ALS) - a neurodegenerative disease - is specifically designed to enable health information sharing and support by peers [7]. That is, current treatment information is shared with others, as well as diagnoses and alike. One of the study's main findings was that the revelation of symptoms, treatment and health, respectively, disease progress triggered targeted messaging, like recommendations to others, requests for advice, or simply building relationships with patients sharing similar experience. Among 123 postings that were selected for analysis 23% (n=29) referred to treatment, whereas 7% (n=9) referred to symptoms or outcomes.

A study among Australian health professionals (n=935) investigated trends of social media adoption for healthcare [15]. It was found that 9.5% used social media for (professional) health purposes, whereas 19.1% reported personal usage only. The majority (71.3%) reported to not use social media at all. Not comprehending how social media can be used for the health sector was the most common reason for non-adoption of social media (83%), followed by face-to-face communication preferences (53.1%). Other factors were attributed to lack of time (50.9%) and reasoning that social media fosters addiction (49.6%).

C. Second opinions in healthcare

Vashitz et al. [17] found out that, in a survey with 332 participants (orthopedic surgeons: n=172; neurologists: n=160) surgeons were more likely to be affected by a primary opinion than neurologists. The study group was given the information about the opinion itself, the control group had only revealed that the patient already had an opinion, without saying what it was. It was shown that interventional scores for study group surgeons were significantly higher than for control group surgeons (2.25 vs 1.97; $p = 0.03$). Also, significant difference was identified comparing study group surgeons in interventional scores in relation to their baseline interventional score. No significant differences were found among neurologists.

The possibility of obtaining a second opinion is listed as a reason to collect medical data at home by Austrian and German citizens [16]. Among a sample of 151 Austrians and

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137 Germans, 13% versus 6% reported to do so. Much more common reasons were insurance issues (36% versus 17%) and understanding one's treatment (25% versus 23%).

A study at the Sydney Cancer Centre revealed that 123 out of 1,892 outpatients sought a second opinion [10]. Those whose motives were dissatisfaction (compared to others) reported that the second specialist helped with their concerns (92% vs 37%, $\chi^2_1 = 11.92, P = 0.001$). Other findings were that younger, more educated, female cancer patients are more likely to seek second opinions, maybe because they want to obtain more detailed information.

III. METHODS

The study design was divided into the three stages: research, construction, and realization (see Figure 1). First of all, a literature review was conducted to identify current research about content and functions of an information system in the health sector and second opinions in the context of telemedicine applications. After doing some brainstorming, the study setting was defined. The target population included individuals being older than 18 years of age, whose profession is not a medical one. In a next step, a questionnaire was developed, which was in turn evaluated and refined after having performed a pretest on it with 15 participants. Questions asked were of both open-ended and closed nature. Additionally, questions with four-level-based items were included to avoid a central tendency bias. A fifth point was provided in case a question was not applicable to a participant. The questionnaire was then administered to a sample population of the target group in different courses at the Vienna UT. 56 people returned it. To analyze the results, four-level-based question items were subsumed and transformed to yes/no, respectively, positive/negative answers.

IV. RESULTS

The questions asked can be looked up in Table I. Specific questions are represented as "Q <XX>" within all figures. Due to limited space, the percentage and actual number of people who indicated a specific answer is not depicted in the graphical charts, if it is less than 5%. Instead, the exact numbers are given in the textual description. The categorization of the question was done afterwards to have a better overview.

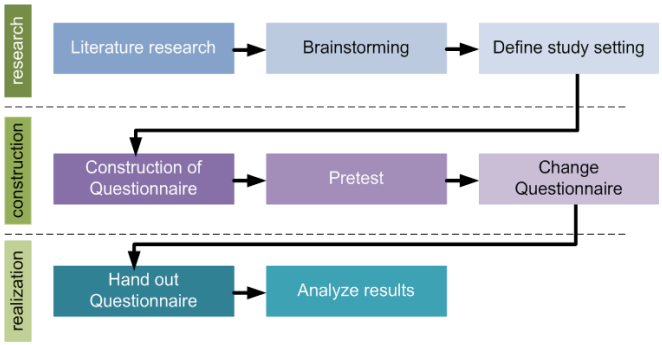

Figure 1. Methodology

The participants were separated into four age groups: age 18-25 (61%, n=34), age 26-35 (29%, n=16), age 36 – 49 (5%, n=3), 50 and older (5%, n=3). To check if a person is used to a PC or not, a control question was asked. The threshold was two hours daily in front of the PC. Only 16.1% spend less than two hours working with it, so most of the participants are computer affine.

TABLE I. QUESTIONS

Nr	Question
01	What's your age?
02	How much time do you spend in front of the PC?
03	What do you associate with the term health?
04	How important are the above stated points?
05	How important is healthcare for you?
06	How important is the security of medical data for you?
07	Would you use electronic devices to measure your sport activities? (mp3 player, cell phone, pulse monitor, software etc.)?
08	If "yes" - which devices and appropriate programs? If "no" - why not?
09	Would you like to administrate and collect your complete training progression online?
10	Do you look up possible diseases before a consultation?
11	Do you look up possible treatments before a consultation?
12	Do you inform yourself about diagnosed illnesses after a consultation?
13	Do you inform yourself about diagnosed treatments after a consultation?
14	Would you inform yourself about a disease and its treatment on a website?
15	Imagine you need a nonacute appointment with your doctor, how would you like to arrange it?
16	Would you prefer to use an information system (website) to make a nonacute appointment regarding your last answer?
17	Could you imagine to schedule appointments via a website?
18	Do you keep old diagnostic findings?
19	Would you use a website, where you can securely administrate old diagnostic findings?
20	A second opinion is an independent diagnosis of a different doctor. Have you ever had a second opinion?
21	How would you like to get a second opinion? (in person from a different doctor, internet research, etc.)
22	Would you use the opportunity to get a second opinion over the PC?
23	Would you do a whole medical consultation virtually over the PC, if possible?
24	Would you like to get a second opinion in the course of a consultation over the PC?
25	Would you transmit medical data for the use of an online consultation?
26	What would you like to have online via PC from a doctor? Please choose at most 3 answers.
27	Which of the following functions within an information system (website) would you use? Please choose at most 5 answers.
28	What should an information system have or which functions should it cover for you to use it? You can also choose functions stated above, if they are true.

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A. General Information

Obtaining general information from respondents is covered by questions 1, 2, 26, 27 and 28.

For question 26 the participants had the possibility to choose up to three answers. The majority of the asked participants wants information about diseases (n=28) and food (n=28) from an online doctor. The answer with the highest credit was giving a prescription (n=29) via PC. A significant number of people (8 out of 56) do not want anything from an online doctor. See Table II and Table III for all answers.

Only 25 people addressed the question of what an information system should cover (Q 28). Six out of 25 people (24%) stated that security of their (medical) data is very important and that they want to be in full control of the data. Four people (16%) only desired a personal doctor's consultation. One person wrote that the system should not require user's personal data. Another one fancied a translation of medical data in case of emergency while being in a foreign country. Further answers noted were allergy information, administration of old diagnostic findings, information/rating of a doctor, reservation system, easy access, reminder of upcoming consults, having more than one online profile, newsfeeds about medical/sports innovations/knowledge, and a friend finder to get in contact with people who share the same disease.

B. Diagnostics and Security

One of the most important questions is one about data security (Figure 2). For more than half (60%) of the respondents security of medical data is very important, for 21% it is important and only for 17% it is less or not important (Q 6). Unsurprisingly, 76% of the asked participants keep their old diagnostic findings (Q 18). Only 40% would store their old diagnostic findings online on a secure website (Q 19).

C. Health-Related Questions

One of the first questions was about participants' associations with the term health (Q 3). More than one item could be chosen from a list of answers. In addition, respondents could frame their own answers.

TABLE II. ANSWERS FOR Q 26

Answers	Count
Issue a prescription	29
Dietary information	28
Information about different diseases	28
Establish a training schedule	20
Nothing	8
Do online consults	7
Diagnose someone based on virtual consults	6
Diagnose someone based on previously transferred health record	6
Sign someone off sick/healthy	1

Healthy food and sports activities are topmost chosen answers that are associated with health. A great number of 37 people think that drug abuse, too much smoking and alcohol consumption are not healthy. 28 times people mentioned that preventive medical check-ups are also related to the term health.

TABLE III. ANSWERS FOR Q 27

Answers	Count
Consultation on refreshing vaccinations	28
Schedule appointment with any doctor	28
Evaluating a doctor and their performance	23
Archive/manage old diagnostic findings	22
Dietary consults	19
Consultation on different diseases	16
Consultation on treating a disease using home remedies	13
Consultation on pollen flight regarding allergy sufferers	13
Consultation on treatment/therapy of specific diseases	12
Graphically represent training success with charts	12
Manage allergies and antibiotics intolerance	11
Establish a training schedule	11
Online transfer of medically relevant data to one's respective doctor	6
Documentation of performance/achievements in sports	6
Archive/manage one's health record respectively one's relatives' health records	6
Nothing at all	6
* check for antibiotics intolerance	1

In question 5, the importance of health protection is shown. 14% (n=8) thought of it as very important, while 66% (n=37) said it is important. 13% (n=7) felt it as being less important, while 7% (n=4) indicated it is not at all important for them.

D. Sports activities

The majority (73%) wants to use or still use a device to measure their sports activities. Only 14% do not want to use a device and the last 12% gave no answer to this question (Figure 3 Q 7). Looking at the number of people who want to use a device to measure their sports activities, only 14% strongly agree and 23% agree that they want to administrate and manage their complete training progress online. 30% do not want this and 26% of the asked people strongly disagreed on that. Furthermore, 5% (n=3) were not sure what to answer

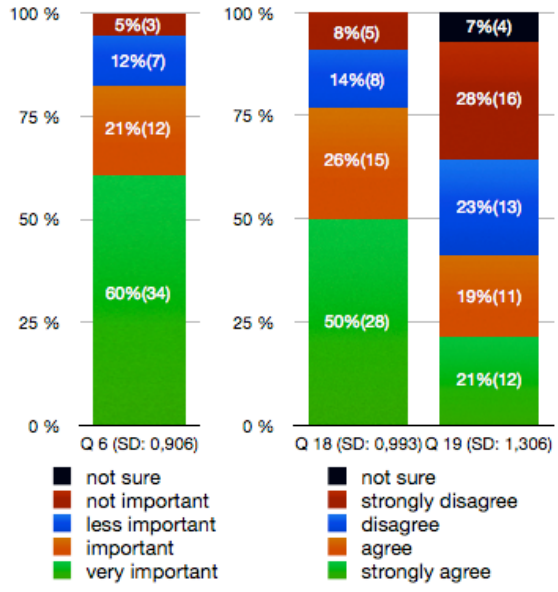

Figure 2. Diagnostics and security

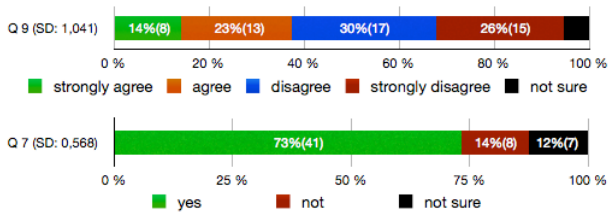

Figure 3. Using device during sport

to this question (Figure 3 Q 9).

E. Consultation and Diseases

Prior to seeing a medical professional, potential treatment options are investigated by 23%, who agree and 16%, who strongly agree, compare Figure 4 Q 11. 41% do not agree to inform themselves before a doctoral visit, 20% indicate strong disagreement. Similar but more positive feedback is given for question 10. 16% (n=9) strongly and 25% (n=14) still agreed on that question, whereas 23% (n=13) strongly and 35% (n=20) disagreed which is shown in Figure 4 Q 10.

Furtheron, 41% reported strong agreement towards informing themselves about their diagnosis after they had seen a medical professional, whereas 38% agreed to doing so, compare Figure 4 Q 12. Disagreement and strong disagreement was found in 19% respectively 2% (n=1) of the total number of respondents.

A similar tendency can be observed once asking about suggested treatment by medical professionals and if patients educate themselves after their doctoral visits (see Figure 4 Q 13). The majority of the respondents indicated to do inform themselves about treatment options. 15 people strongly agreed (26.79%), 24 people agreed to doing so (42.86%). 14 people disagreed (25%) upon answering this question and 3 people strongly disagreed (5.36%). Conform to the findings above, nobody chose the neutral answer of being unsure.

Looking up information about one's conditions and available treatments at designated websites was perceived rather positively by respondents, compare Figure 4 Q 14. 19 persons strongly agreed to educating themselves (33.93%),

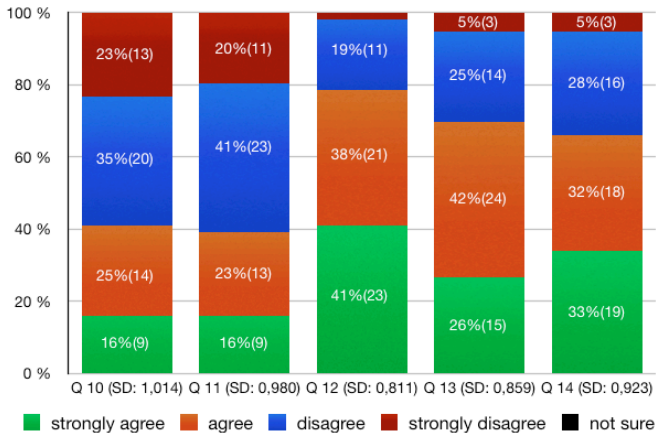

Figure 4. Consultation and diseases

whereas 18 people agreed (32.14%). Only 19 people disagreed to taking responsibility as in informing themselves about their options (28.57%), whereas three of them strongly disagreed (5.36%). Nobody indicated to not being sure about this topic.

F. Doctoral Appointment

Questions 15-17 focus on different ways to schedule appointments with one's doctor. Answers for question 15 were cell phone (66.04%, n=35), face-to-face (13.21%, n=7), email (11.32%, n=6), online web form (1.89%, n=1), online reservation system (1.89%, n=1), online calendar of doctor (1.89%, n=1) and online website (1.89%, n=1). Questions 15 and 16 show that most people will use their cell phone for contacting a doctor for a nonacute appointment rather than an online platform (39%). One person gave no answer to this question.

In general, 36% would strongly agree and 30% agree to schedule an appointment via a website. A number of 32% would not do this and only one person was not sure what to answer. All values regarding question 16 and 17 are in Figure 5.

G. Second Opinion and Virtual Consultation

Exactly 50% of the sample population indicated they had obtained a second opinion before. 43% had never done so and 7% could not remember or were not sure (question 20). Upon responding to question 20 the participants were asked how they want to get a second opinion (Q 21). It was possible to choose more than one answer. Most people (n=40) obtain their second opinion from another doctor in person. The second most common answer was the web research and only three people would get a second opinion from a friend. A great number of 13 people (23%) gave no answer to this question. Answers for question 21 were personally (n=40), web research (n=10), friends (n=3) and no answer (n=13). To follow up, respondents were asked if they would use the opportunity to obtain a second opinion via their PC (question 22), see Figure 6 Q 22. 30% agreed and 5% strongly agreed. Among the majority of 33 people who disagreed, 21% had a strong disapproval regarding this topic. 5% indicated to not being sure about electronically consulting a doctor other than one's primary choice. 61% strongly denied using an opportunity to do an entire medical consultation virtually over the PC, compare Figure 6 Q 23. Only 9% were in favor of such an opportunity and 25% disagreed to use it. 5% felt unsure about their answer to this question and no one would strongly agree.

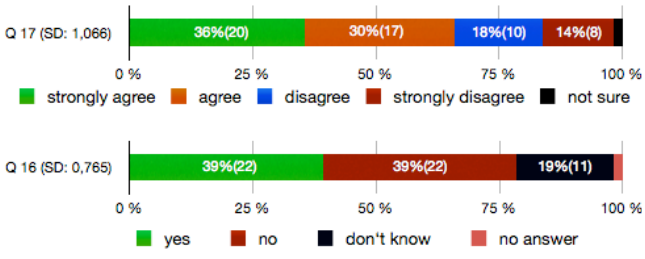

Figure 5. Doctor appointment

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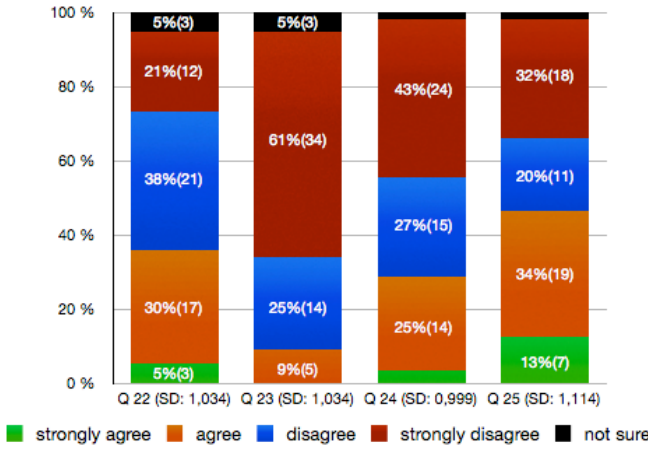

Figure 6. Second opinion and virtual consultation

Respondents were asked if they would obtain a second opinion by the use of online, i.e., virtual, consultation hours via the PC, see Figure 6 Q 24. Results show a tendency towards disagreement: 27% versus 43% disagreed respectively strongly disagreed. 25% seemed rather positive towards this topic, whereas 4% (n=2) strongly agreed. Only one person (1.79%) indicated to be not sure about what they would do.

Although most people would not use a second opinion via PC and would not store their diagnostic findings online (question 19), 47% would forward their medical data during an online consultation. This is shown in Figure 6 Q 25.

V. DISCUSSION

The work presented here gathers information about second opinion and the usage of modern media for health-related topics. Although the sample size of 56 is not the biggest, it can be seen as a good starting point for further research. The results show that security is very important when it comes to health-related data. In terms of health and diet, people want to have more information about diseases regarding nutrition, which might be associated with the wish of a healthy lifestyle and the support of the doctor to help them. Another interesting aspect is that the skepticism for a virtual doctor consultation is very high. This might also be associated with security issues, but needs to be clarified within further research. Another bias of this research is that the majority of returned questionnaires was answered by younger people (age <35), only a few came from people older than 35. But the authors consider younger people as a target group for second opinion and the usage of modern media, which makes this age group very important. Further research should include a larger sample size as well as a quantitative study and a comparison between different countries and different educational aspects, which were also not taken into consideration within this work.

VI. CONCLUSION AND FUTURE WORK

As a final result, people do want to have additional information through other channels rather than from the doctors themselves. The results suggest that a virtual consultation or second opinion without direct patient contact will never be a full alternative to the normal doctor's visit. To prove this, additional data must be acquired. Follow-up studies are necessary to support the trends presented here. A study with a larger sample size as well as more heterogeneous age distribution is taken into consideration.

ACKNOWLEDGMENT

The authors would like to thank everybody who took the time and answered the questionnaire.

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Field Testing of Remote Teledentistry Technology

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Abstract—**In the Australian state of Victoria, only 11% of nursing home residents have seen a dentist in the past 12 months. This study tested whether the use of intraoral cameras by oral health professionals located at remote facilities improved access to appropriate oral health care services for nursing home residents. The support program and instructional kit for camera operators, including the structure, content and delivery of the program, was developed and evaluated. Residents' views about the structure, content and delivery of the program were also evaluated. The intraoral camera was operated by trained teledentistry assistants with the aim of screening residents for oral diseases and pathological conditions. Treatment plans were then developed by remote oral health professionals based on the information collected. The remote assessments were compared with those done via traditional face-to-face oral examinations. Results indicate that the proposed teledentistry approach for oral health screening is feasible and reliable as an alternative to traditional oral health examination. Residents expressed high levels of satisfaction with the teledentistry service. This study provides an innovative solution towards closing the gap in the provision of sustainable oral health care services to underserviced populations (e.g., nursing homes, rural areas).**

Keywords; oral health, teledentistry, intraoral camera, nursing homes

I. INTRODUCTION

Improvements in oral health in Australia over the past 50 years have translated into a greater proportion of elderly individuals retaining more of their natural teeth, increasing the prevalence of caries and periodontal disease. Older people living in residential aged care facilities (RACFs) have been identified as a significant risk group for oral diseases in Australia, and the changing demography and oral

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health needs of older Australians will present many challenges for the dental profession over coming decades. In 2005 more than 41,000 Victorians lived in high or low-care residential facilities on a permanent basis; with just over half being dentate and having high dental treatment needs [1,2]. Significant barriers accessing dental services exist. Residents are often physically and cognitively impaired, medically compromised and dependent on others to maintain their oral hygiene.

Face-to-face patient examinations are regarded as the most accurate method for correct oral health diagnosis. However in Victoria only 11% of aged care facility residents have seen a dentist in the past 12 months, as there are few dentists available to provide dental care for residents [3,4]. In fact, only half of Victorian dentists reported providing care to residents of RACFs, and those dentists spent on average only one hour per month providing care in this setting [4].

As the capability of information and communication technology (ICT) has risen, the use of ICT for data collection has increased. Expanded use of ICT provided clinicians with alternatives to the traditional face-to-face oral examinations. This shift in focus has resulted in a vast increase in the number of published articles that include some form of either synchronous or asynchronous, teleconsultation/ telediagnosis [5].

A three-stage study was designed to address priorities established by Australia's National Oral Health Plan 2004-2013 for 'Older People' targeting older people living in RACFs, (an underserviced, high-risk population and one with major oral health needs) [6]. This project was conceived in an effort to promote affordable, timely oral health care and to test an oral health care model in which ICT is used with the aim of extending clinical care to residents who are physically separated from the examining oral health professional. This study is also a response to serious dental workforce shortages in caring for this group and provides opportunities to supplement traditional methods of oral diagnosis, care delivery and health promotion.

Potentially, this project could benefit an expanding segment of the population in relative and absolute terms; namely, older people living in RACFs and older people living in rural areas. According to the 2006 Australian Census [7], 55-64 year-olds made up 11.8% and those 65 years and over 13.7% of the total Victorian population.

However, older people are proportionately over-represented in rural and regional Australian communities and these communities are ageing more rapidly than their metropolitan counterparts. Therefore, the present intervention potentially targets a rapidly expanding segment of the population with special oral health needs. Other parts of the world have similar demographic and geographical problems making this study equally relevant to them.

This project builds on a University of Melbourne Institute for a Broadband Enhanced Society (IBES), Project Seed Grant, which tested the technology under laboratory conditions (proof of concept) and developed the instructional material for non-oral health professional operators [8]. The results demonstrated that the proposed teledentistry approach for oral health screening using an intraoral camera was feasible and reliable as an alternative to traditional oral health examination. Stage 2 of this three-stage study involved the field testing of this teledentistry technology and is the subject of this article.

II. AIMS AND OBJECTIVES

The long-term goal of the project is to test whether improvements in accessibility and appropriateness of oral health services can be achieved by utilizing advanced ICT techniques to screen for oral disease in older people living in RACFs. This paper outlines the results of the second stage of this project, which aimed to assess, on a small scale, but under real conditions, the safety of the procedures, their feasibility, as well as patients' and health practitioners' experiences with the technology. A comparison was conducted between face-to-face-examinations and remote examinations using an intraoral camera.

Three RACFs within the state of Victoria, Australia, were successfully approached to participate in this stage; two in metropolitan Melbourne and one in rural Victoria. Five non-oral health professional teledental assistants (e.g., registered nurses) in these facilities were trained to manipulate an intraoral camera and use existing and introduced ICT infrastructure to transmit video images for remote examination and diagnosis. An oral health professional at the Melbourne Dental School performed a 'virtual dental examination', recorded findings and developed a treatment plan for a group of selected residents.

This Stage had four main objectives:

1) assess the feasibility of using teledentistry to screen for oral diseases and conditions and to develop treatment plans for older people living in RACFs;
2) identify barriers to the adoption of a teledental approach. These included: a) general staff workload; b) professional culture and acceptance (e.g., morale, motivation, resistance to change, etc.); and c) availability of appropriate equipment,
3) test the utility of an instructional training kit
4) assess the residents' views of their experiences during delivery of the program, as well as feedback and information provided during the teledentistry consultation.

III. METHODS

Although sample size calculations are not strictly necessary for a pilot study [9], a sample size of 50 residents was considered to be adequate to meet the general aims of this study. A 20% attrition rate was expected over the six months duration of the field component of this study - 62 residents were recruited initially.

To participate in this teledentistry study, the resident was required to have the ability to understand and to provide independent informed consent, the ability to communicate with the health professional and to undergo a 15-20 minute oral examination.

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A SOPROLIFE® intra-oral camera was used to capture video via a custom video streaming software platform designed for the project [10]. Simulations were conducted in the Institute for Broadband Enabled Society (IBES http://broadband.unimelb.edu.au/) test-bed facility. The intra-oral camera was connected via a USB cable to a laptop or mobile tablet used for bed side evaluations, containing the software that compressed and encoded the 25 frame-per-second video into an mpeg4 video stream of at least 3Mbit/sec bandwidth, and preferably a 5Mbit/s stream if network conditions allowed. This bandwidth was found to give the clinician sufficient quality to interpret the images received and removed blurring due to the motion of the camera [8]. The clinician viewed the incoming video via a PC connected to a large monitor. A large screen facilitated simultaneous viewing of both the intra-oral camera video as well as that from a second web-cam, a high definition Logitech model C920 model, capturing the overall interaction between patient and the intra-oral camera operator. This was also streamed as an mpeg4 video of minimum 3Mbit/sec bandwidth. Mpeg4 audio was also transmitted at 128kbit/s along with the images via the use of Clear One Chat 50 model microphone/speaker units also connected via USB cables. This allowed excellent quality audio communications between patient and clinician ends. For test sites that could not accommodate a 3Mbits/s stream reliably a Store and Forward version was developed that enabled the mpeg4 file to be stored on a central server for asynchronous download by the dentists. Each examination lasted approximately 15 minutes and each minute of video created a file of approximately 1GB. Thus, the video files were large (i.e., 15 minutes produces a 15 GB file).

Using a teledentistry installation each participant received a 'virtual' oral examination, including dental and oral mucosal assessments conducted with the assistance of a trained registered nurse (RN) at the RACF's facility using an intraoral camera operated in communication with a remotely located oral health professional. Training of the intraoral camera operator involved three hours of direct contact, a sixty-six page training manual including diagrams with content organized in five modules, and up to ten hours of practice examinations.

The oral health professional was able to communicate in real-time with both the resident and the intraoral camera operator (i.e., the RN) via a video link to assist in taking a history, and to direct the RN where necessary in the use of the intraoral camera. To have communication in real time we used Skype® and Vidyo®. However, there were several problems with Vidyo due to firewall settings.

The information obtained from this examination was recorded and transmitted to a server for review of the 'virtual dental examination' to be performed remotely at a later time. Information was registered on a conventional Dental Health Services Victoria's chart for the generation of treatment plans by qualified clinicians at the Melbourne Dental School, University of Melbourne.

On completing the virtual oral examination the resident was asked to complete a seven-item teledentistry assessment questionnaire to assess his/her views on the approach. As further verification of the approach, the interaction, the clarity and facility to understand communication between the oral health professional and the resident was examined for the conventional face-to-face and remote communications.

Ten residents received a second oral examination by a different oral health clinician. This was a traditional real-time examination (the clinician present in front of the patient) with findings recorded on a conventional chart.

RNs who collected the information for this project completed a questionnaire to assess their initial attitude to, and acceptance of the practice, and their overall experience with the teledentistry approach. The utility of the instructional training kit and any other issues associated with the project were also assessed.

Data was collected extended between October 2012 and June 2013.

Descriptive analysis was used to illustrate the participants' views about the format, content and delivery of the teledentistry program. The level of inter-examination reliability for the degree of consistency of the two sets of examinations has been assessed using the kappa statistic.

Ethical approvals to conduct this study were sought and obtained from the University of Melbourne

IV. RESULTS

Fifty residents from three RACFs participated in the trial from the 62 initially recruited; with 58% being female. A teledentistry installation enabled five trained intra-oral camera operators (registered nurses) to record, use and transmit video images for the generation of treatment plans by qualified clinicians at the Melbourne Dental School, University of Melbourne. Information from the remote examination was compared with a real-life dental examination. The intra-examiner agreements for dental examination parameters were reported as excellent (Kappa=0.83).

When residents were asked about their level of satisfaction with the examination, the majority of the residents were either very satisfied: (46%) or slightly satisfied (38%) with the format of the remote dental examination. The majority would also recommend (strongly: 46%; or slightly: 46%) a remote dental examination to other people of their age and background. When asked about the reason for not recommending this assessment, the comments were related to the lack of provision of oral health services, in particular preventive care (See Table I).

The majority of the residents considered the format of the remote dental examination to be either highly appropriate (46%) or slightly appropriate (46%). On the other hand, three residents (6%) were neutral about its format and one resident (2%) considered remote dental examination to be slightly inappropriate. No reason was provided for that view.

When asked about how satisfied they were with the review of oral health needs, although the majority was either satisfied (46%) or slightly satisfied (32%), three residents (6%) were neutral and, more importantly, 16% were slightly dissatisfied. Asked about the reason for this dissatisfaction,

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most residents' comments were related to the lack of immediate feedback on the examination.

On comparing residents' opinions on the clarity of the communications received with the face-to-face examiner (i.e., the RN), 86% of the respondents found it "Very easy", and another 12% "Easy" to understand. On the other hand, residents found it generally easy to understand remote communications (46% "Very easy" and 46% "Easy"), and another 4% were neutral about it. Nonetheless, the remainder 4% found it "Difficult" or "Very difficult" to understand remote communications. Residents who found it difficult to understand indicated that the comments were related to the foreign accent of the oral health professional that provided feedback on the examination, rather than the technology used.

TABLE I. RESIDENTS' RESPONSES TO TELEDENTISTRY ASSESSMENT QUESTIONNAIRE (%)

1. How satisfied were you with the remote dental examination?				
Strongly satisfied	Slightly satisfied	Neutral	Slightly Dissatisfied	Strongly dissatisfied
46.0	38.0	14.0	2.0	-
2. If remote examinations were available for patients, would you recommend them to other people?				
Strongly recommend	Slightly recommend	Neutral	Slightly not Recommend	Strongly not recommend
46.0	46.0	4.0	2.0	2.0
3. How appropriate was the format of the remote dental examinations?				
Very appropriate	Slightly appropriate	Neutral	Slightly Inappropriate	Strongly inappropriate
46.0	46.0	6.0	2.0	-
4. How satisfied were you with the review of your dental needs by the remote dentist?				
Strongly satisfied	Slightly satisfied	Neutral	Slightly Dissatisfied	Strongly dissatisfied
46.0	32.0	6.0	16.0	-
5. Were instructions from the examiner in the face-to-face exam clear and easy to understand?				
Very easy	Slightly easy	Neutral	Slightly Difficult	Very difficult
86.0	12.0	2.0	-	-
6. Were instructions from the examiner in the remote examination clear and easy to understand?				
Very easy	Slightly easy	Neutral	Slightly Difficult	Very difficult
46.0	46.0	4.0	2.0	2.0

Over one quarter of the residents (28%) commented that the most valuable element of the remote dental examination was its convenience. For example, by taking video images in the RACF, residents could avoid the disruption, difficulty and cost of arranging travel to visit a dentist.

Three of the five RNs that had been recruited and trained conducted intraoral examinations with the RACF's residents. Nonetheless, most of the exams (n=28) were conducted by an oral health professional. In another eight examinations, RNs were assisted, either remotely or at the RACF, by an oral health professional on how to properly manipulate the intraoral camera and transmit video images. The RN performed the examination and could transmit the videos by themselves without supervision in 14 examinations (See Table II).

These three nurses provided feedback on the training material presented (i.e., a hard-copy, on-line manual and demonstrations). There was general agreement that the material presented was clear and relevant to the purposes of this project. RNs also agreed that the length of the material was right. The information about oral health in older adults was considered too long and less relevant to their work.

TABLE II. NUMBER OF TELEDENTAL EXAMINATIONS COMPLETED BY INTRAORAL CAMMERA OPERATOR

RACF[a] Location	Examinations			
	Nurse no supervision	*Nurse under supervision*	*Oral health professional*	*Total*
Urban 1	6	4	11	**21**
Urban 2	4	0	3	**7**
Rural	4	4	14	**22**

a. Residential aged care facility

However, when asked about the relevance of the teledentistry model in their workplace, they were neutral with some indicating that teledentistry might only be relevant to low-care residents, as the model may not be practical in high-care due to dementia and decreased physical capability.

V. DISCUSSION

The present study tested the technical feasibilty and acceptance, by both users and residents, of an alternative model to the traditional face-to-face oral health examination using a teledentistry installation. The results provided evidence that the proposed approach for oral health screening proved to be feasible and reliable as an alternative to traditional oral health examinations. On one side, the observed concordance of remote and face-to-face exams was high. On the other hand, residents expressed acceptable levels of satisfaction with the teledentistry model.

The 'virtual dental examination' can provide general and specialist oral health care support to local aged care facilities. It can assist in providing regular and timely oral health checks using trained non-oral health professional assistants in the first instance.

Additionally, there is anecdotal evidence from RACF staff that the stress imposed by travel to a dental surgery can lead to complete non-compliance with the dental examiner, to the point where attempts at oral examination are abandoned. This leads to further travel and dentist re-booking costs and often reluctance on the part of resident and practitioner to repeat the process. By using the teledentistry approach, RACF avoids the disruption and difficulty of arranging travel for the patients for dental treatment. A successful translation of this technology into clinical practice would extend the provision of health care/oral health care to remote and difficult-to-serve locations, and improve access

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for care to additional patient populations at a reasonable cost, as well as easing the shortage of oral health professionals.

The ability to view examination results at their desktop will enable oral health professionals to see and screen more residents per time unit in their catchment area. Further development of the procedures is warranted to allow for high-care resident assessment. Specialist dental services can subsequently be provided when the required treatment is identified.

Oral health professionals will also be able to triage and prioritize appointments, rather than travelling to each home without knowing beforehand what treatment each resident will require. Visiting domiciliary oral health professionals will be aware of the exact nature of the oral problem before they arrive. The oral health professional will also be able to plan a visit to treat other residents in the area, improving efficiency and meaning that more residents are able to be treated over the course of the year. The oral health professional will also be provided with better means of identifying older adults who require a diagnostic examination by a dental specialist.

Furthermore, by performing an in-RACF examination, the confidence that both the residents and the residents' families have in the RACF will increase. From the health care system and societal perspective, a key impact will be in the satisfaction of knowing that residents have been well looked after, and that scarce resources are being well utilized. Additionally, the case for extension of funding would be bolstered. It will improve oral health for underserviced communities through education, diagnosis, treatment, health promotion and disease prevention.

Data collected from this project could also be useful as a starting point for a large oral health record repository, which would combine a digital record with 2D and 3D stills and video images, as well as radiographs.

Additional research should explore and address some technical and training aspects of this study, as means of further verification of this approach. Firstly, when the interaction during the conventional face-to-face exam and remote communications was examined, there were significant differences between remote and face-to-face consultation. The face-to-face, provided a more effective mean to achieve clarity and easy to understand communication between the oral health professional and the resident. In the present study it appears that this was due to language and not technical aspects, but this was not explored. However, King and his collaborators [11] reported diminished quality of communication with videoconferencing. Secondly, although adequate training and material compensation to the RACFs for the RNs time was provided, some still failed to fully engage with the study despite the successful use of RNs in other areas of dentistry [12,13]. The perception that this technology is of limited use in RACFs could explain, at least in part, the willingness to take up this new technology [14]. In any case, it seems that barriers to implementation are mostly human factors. Further training and analyses of how different types of constraints operate to support or undermine the adoption of a teledentistry model need to be explored and addressed.

VI. CONCLUSIONS

Findings for this field trial indicate that using a teledentistry installation is an appropriate alternative to traditional oral health consultation, and could provide benefits to an expanding segment of the population in relative and absolute terms. This population comprises older people living in RACFs and older people living in regional, rural, and even outer-metropolitan areas.

An increasing proportion of older people are living in rural and regional Australia and these communities are demographically ageing more rapidly than their metropolitan counterparts. Intervention projects such as the present one have the potential to target the rapidly expanding aged segment of the population with special oral health needs. There is also potential for wider scale application for the provision of sustainable oral health care in rural areas. Nonetheless, involvement of a wider range of stakeholders might be necessary, as they all influence adoption. Recently, a review of factors influencing the implementation of teledentistry, highlighted some challenges at different levels [14]. These challenges need to be specifically targeted.

This study will lead to a multi-State, community-based trial of the technology. This will require further research into the acceptability of teledentistry by participants, including the format, content and delivery of the program, as well as the relevance and appropriateness of the information provided.

Further research will also be required to undertake economic analysis and modeling to determine the interventions productivity compared to the traditional model of oral health examination.

ACKNOWLEDGMENTS

This project was funded by a grant from Dental Health Services Victoria's Research and Innovation Scheme and the Victorian Department of Business and Innovation BEIP program. We would also like to acknowledge the RACFs, residents and nurses involved in this study.

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Organising Videoconferencing for Collaborative Medical Diagnosis

Pre-Planned and Acute Practice

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***Abstract*— How videoconferences (VCs) as a tool for real-time collaborative medical diagnosis are organised affects the content of collaborative work. The objective of this paper is to outline *how* the organisation of VCs for pre-planned and acute situations affects content in collaboration. Forty-seven VCs were observed and videotaped, and twenty semi-structured interviews were conducted in two studies, representing three contexts, reflecting pre-planned and acute medical problem solving. Regularly pre-planned meetings differ from others, creating a practice that includes consultations about general medical problems, the opportunity to discuss specialised problems, and information sharing between levels of care. Regularity and thus knowledge of each other and of the patient support the sharing of information about patients previously discussed. Acute use of VC is organised as a restricted service, offered during a specific timeslot during the day. The consultation is specialised (i.e., stroke), in which professional(s) with specific specialised knowledge meet. Non-planned, 24/7 acute use of VC is still left to be explored in its context. What is known is that acute knowledge is knowledge in the moment, requiring unplanned access to VC as a tool for sharing knowledge resources twenty-four hours a day. These factors should be considered when VC is implemented for collaborative medical diagnosis. The paper is relevant as it is concerned with tools to enhance collaboration online, i.e., VC, and how VC improves the value of distributed knowledge among virtual teams.**

Keywords—videoconference; Collaborative medical diagnosis; context; pre-planned; acute

I. INTRODUCTION

Videoconferencing (VC) is a well-known technological tool for collaborative work. Through the use of VC, professionals can share information and knowledge jointly, producing real-time collaborative medical diagnosis. In previous work, the results illustrate that how the VC is organised in pre-planned meetings affects the content of collaborative work [1, 2]. Continuing work with VC in unplanned acute situations [3] led to an interest in how the organising of the VC as a tool affects content in the collaboration between the professionals. How the use is organised is important for the content of collaborative work. The objective in this article is therefore to explore how different ways of organising the use of VCs affect the content of the collaboration and to outline how successful VC for collaborative medical diagnosis can be organised. This paper expands previous work by connecting the two contexts, to illuminate the differences to be considered when implementing VC in practice.

Studies on the organisation of VC have treated the tool as a technology disconnected from the context it is a part of, e.g., creating ten simple rules for organising VC anywhere [4] or a step-by-step guide to VC [5]. Several factors influence the VC practice, the context in one main factor. The effect of context is often related to a medical illness, i.e., VC between specialists and general practitioners (GPs) aimed at improving the quality of diabetes care [6], addressing administrative and clinical issues using VC in delivering psychiatric care [7], and using VC as an effective diagnostic tool for, e.g., skin lessons in dermatology [8]. In workplace settings, studies have, in many situations, been more focused on the technology used during the interaction than on the interplay with remote colleagues [9]. This work merges two different contexts, to illuminate how medical situations are unequal, demanding a different organisation. This is often overlooked when implementing new technology, as one solution is developed to cover, i.e., all acute medical situations, even all collaborative work. This expands novel knowledge to the field.

The paper focuses on collaborative work between distributed resources. The theoretical approach constitutes the framework for the studies and the paper, as the perspectives create premises for understanding collaboration in VC practice. The tree contexts, two pre-planned and one acute, are accounted for. Video-recorded observations and interviews are described as the methods for revealing the organisation of VCs and how the context affects the content in collaboration. Based on the amount of and the content in the VC meetings, the results report how collaborative work is shaped by the context. The discussion illuminates pre-planned and acute practice, and what kind of practice and problem solving to arrange for. The paper concludes with suggestions for future work.

II. FRAMEWORK

The interplay among remote colleagues and the emphasis on the context of knowledge sharing is used as a framework for understanding how the content of medical work and the organisation of the VC are mutually shaped. In workplace settings, the situated approach notes that problem solving often occurs in group settings [10]. This situated approach emphasizes a Cultural Historical Activity Perspective (CHAT), which focuses on the connection between the culture, the arteacts, objects, and tools as a social activity

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[11]. Knowledge is situated within the social activity, context and culture and it is an interplay between the institutional context and the organisational structure. The studies do not frame the use of VC nor the collaborative work *itself* as a transmission of knowledge from one individual to another. The collaborative work is shaped by the context it is used and developed in, e.g., the medical culture. That i the tools the professionals use in their work, the rules they follow, the division of labour, and the community they practice in. It is the social activity in the group that develops the practice.

Collaborative medical diagnoses are culturally and historically situated [12], and the contradictions among different professionals might change the traditional treatment of patients. When knowledge from medical professionals is transferred between them by collaboration, it might change their treatment methods. Changing methods for the specific treatment or the tools they use is a change in the historical way of performing treatment. Performing medical treatment is connected to the context in which the VC is the tool that mediates the interactions and activities [13] [14] between the participants. It provides collaborative work and ensures that the meanings are socially shared. The knowledge is distributed as a result of sharing their competence and experience as individuals and as a part of their institutional practice.

III. MATERIALS AND METHODS

Both studies were designed with the purpose of exploring the use of VC, the content for the collaborative work, and distributed knowledge sharing. The VC equipment was implemented independent of the studies explored in this paper. All the participants who used the VC in daily practice were recruited for these two studies. No payment was received for the professionals, since the collaborative work was voluntary as a part of their daily work practice.

There are three contexts in this study: contexts a and b represent hospitals with pre-planned use, and c represents VC in unplanned/acute situations. Figure 1 illustrates how one hospital with one or several general practitioners (GPs) or specialists (coloured faces), with or without patient participation (transparent face), is connected to another hospital using VC as a tool for collaborative medical diagnosis. Traditionally, the professionals in these local hospitals seek a second opinion from the larger specialist hospital over the telephone. VC replaces or supplements the use of the telephone for these activities.

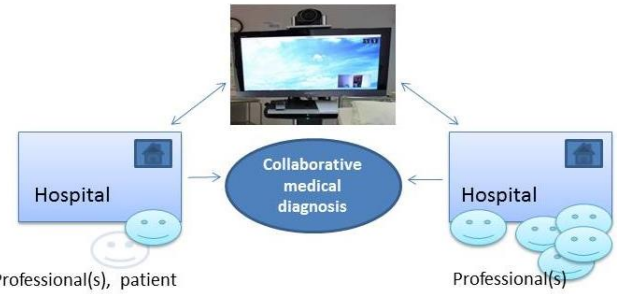

Figure 1. Two hospitals connected using VC as a tool.

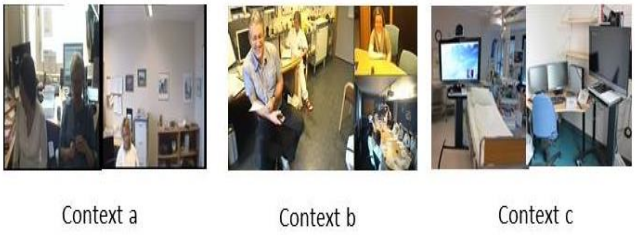

Figure 2. Organisation of the VC in all contexts.

A. *Hospitals with pre-planned use*

The pre-planned use of VC was organised differently in contexts a and b: In context a, the VC is scheduled for a specific time slot once a week and happens 'when needed'. The GP identifies the cases to discuss and makes arrangements the day before with the hospital, which arranges for the appropriate specialist. In context b, the VC meetings are held routinely four times a week, organised as part of the ordinary daily meetings at the hospital. They take place regardless of whether there are predefined medical problems to discuss. This service is still running.

In both contexts a and b, the VC equipment is located in the office of one of the GPs. At hospital A, the VC equipment is located in a smaller meeting and consulting room at the medical department. At hospital B, the VC equipment is located in the morning meeting room in the medical department.

B. *Hospitals connecting in acute situations*

In context c, the VC was connected during restricted times during the day, excluding nights and weekends. This context was associated with the condition of stroke, an acute medical problem. The professionals in the emergency ward assessed the patient and connected to VC from the local hospital's emergency room. At the specialist hospital, the VC equipment is located in a dedicated room used only for this purpose. When they are called by telephone and asked for a VC meeting, the specialist on duty immediately moves to this room (Figure 2 illustrates the physical placement of the VC equipment in all contexts.)

C. *Qualitative methods*

The main data of interest in all three contexts were the social interaction and the content in the VCs, requiring qualitative research methods. For the pre-planned VCs, it was possible to observe the interaction [15]. Forty-seven VCs (five in context a and forty two in context b) were observed and videotaped during the first half of 2007. This constituted all meetings conducted during the five-month period. The purpose of the observations was to illustrate the social interaction, the content of the collaboration, and how the organising affected the content. All the video recordings were transcribed, analysed, and categorised to facilitate an understanding of the content in the VCs.

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Eight interviews with GPs and several of the specialists participating in the VCs, from both contexts, were conducted to evaluate the use of VCs in pre-planned collaborative work. The interviews were semi-structured, recorded, and then transcribed. The interviews lasted from twenty to seventy minutes and were conducted from August to December of 2007.

In the acute situation, context c, observations of the unplanned VCs were difficult. Therefore, all the activity using VC was automatically logged and used as a basis for conducting interviews. Thirteen professionals, nurses, physicians, and specialists from both hospitals were interviewed through twelve semi-structured interviews in the autumn of 2011. Each interview lasted from twenty minutes to two hours. All interviews were audio-recorded and then transcribed. All transcriptions were categorised according to utterances that seemed to be repeated by the practitioners. The purpose of the interviews was to reflect acute medical problem solving and the organising and use of VC.

D. Ethical considerations

The North Norwegian Regional Medical Ethics Committee (REK) approved the design of the study and how the data were collected, handled, analysed, used, and kept in contexts a and b. Context c has been registered and evaluated as a non-report obliged by the REK. The personal data are handled according to the personal information rules in Norway.

IV. RESULTS

In each context (a, b and c), two hospitals are connected (hospital A and B). Hospital A (A) and hospital B (B) use VCs as a tool for practicing collaborative work in diagnosis (Figure 1). Table 1 illustrates the use of VC in all three contexts. The content was categorised according to consultations and information exchange. A consultation consists of discussions about and exchanges related to medical problems, diagnoses and follow-ups. Information exchange consists of updating the conditions of patients treated previously and information about patients transferred between levels of care.

In context a, VC was used five times in two months before they stopped using the service. Four times, the participants reported and discussed a medical problem and once they met to exchange information about a patient discussed earlier.

TABLE I. THE TOTAL NUMBER OF VC IN THE CONTEXTS

Context	Period and purpose of use			
	Period	***Consultation***	***Information exchange***	***Number***
a	2 months	4	1	5
b	5 months	12	13	42*
c	18 months	4	0	4

* The total also includes the category 'practical organising' used 17 times in the same period.

In context b, the VC is routinely held four times a week. During a five-month period, there were forty-two VC meetings. The service is still running today. During this period, twelve meetings were consultations and thirteen involved an exchange of information. In context c, eighteen months passed between the first time and the last time the VC service was used for acute treatments. During this period, they consulted four times regarding four different stroke patients. The service is now locally disconnected.

In Figure 3, the results illustrate how the organisation of VCs for pre-planned and acute situations affects the content of collaboration. Collaborative medical diagnosis is organised in both pre-planned and acute practice. The pre-planned use of VCs is organised as regularly held meetings, in this context four times a week at a specific hour, or reserved for a specific day when a meeting is held when needed. Regularly held meetings offer all knowledge resources available at the time during the morning meeting. The GP can present patient problems more generally and specific medical problems. In pre-planned meetings held when needed, the GP must define a medical problem and report it to the hospital the day before. These meetings are only scheduled one day a week (Wednesdays), so the GP must wait for Tuesdays to report the medical problem to be discussed. Then, the specialist on duty in the hospital prepares and meets to offer a second opinion.

The acute use of VC is organised as a restricted service, offered during a specific timeslot during the day. As the specialist hospital has less experienced staff on duty during the nights, the service is only offered weekdays from 07.30 to 19.30 and Saturdays from 09.00 to 13.00. In between these hours, the local practitioners in the emergency unit determine whether they need to discuss an acute patient with the specialist hospital.

As the purpose of collaborating is to discuss medical diagnoses, the content at all sites involves consultation. In acute situations, the consultation is specialised (i.e., stroke). Here, connecting using VCs is about collaboration concerning a specific acute situation, in which professional(s) with specific specialised knowledge meet. In a pre-planned VC, general (e.g., reviewing a medical record) and more specialised knowledge (e.g., diabetes) issues are examined. The problems might be of the same character, but consultations when needed, only once a week, involve insignificant problems. If it does not appear the day before the report time (i.e., Mondays) the problem must be of a more general character.

However, pre-planned meetings (when needed), held if there are problems to discuss, and in restricted acute situations, involve professionals with this specific knowledge. It might be the same or different professionals participating each time (Figure 3, symbols ☺ = ≠). Regularly held meetings may also include different professionals, but this is rare, as, e.g., during summer holiday among the practitioners, when stand-ins are practicing. Only regularly

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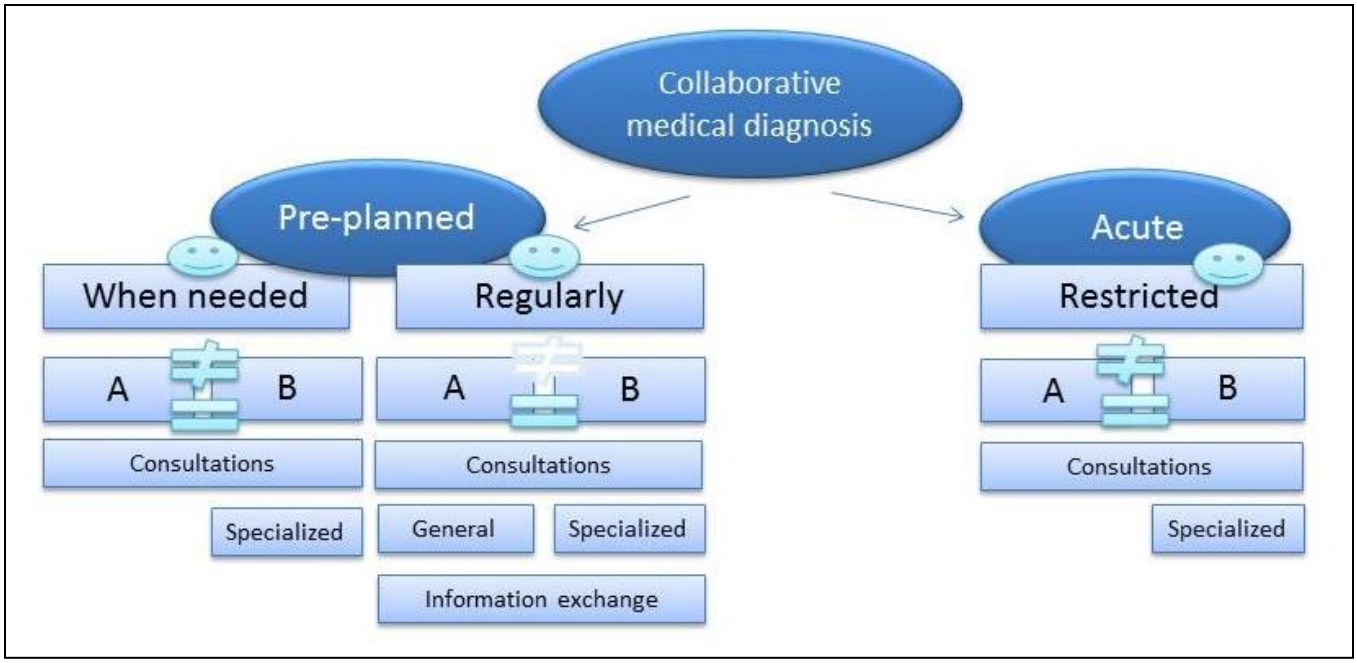

Figure 3. The organisation of VCs for pre-planned and acute situations and the content.

held meetings, where the same professionals (Figure 3, symbols ☺ ≠ =) meet regularly, result in both consultation and information exchange. The regularity and therefore the professionals' knowledge of each other and of the patient support the sharing of information about patients who have been previously discussed.

Regularly pre-planned meetings differ from others, creating a practice that includes consultations about general medical problems and the opportunity to discuss specialised problems and exchange information about patients previously discussed. It also allows the sharing of resources among the same professionals over time, which provides opportunities to expand treatment activity together.

V. DISCUSSION

Based on three contexts, the results show how the organisation of VCs for pre-planned, as-needed, and regular and restricted acute situations affects the content of collaboration. This paper focuses on collaborative work between distributed resources and how the context affects the content and the medical work using VC as a tool for collaboration.

As context b illustrates, VC is well-suited for consultations and medical problem solving. It is the medical condition that determines whether the situation can be pre-planned or is acute. Regularly held meetings, as a part of established activities such as morning meetings, offer an adequate way to organise the use of VC if the aim is a two-way commitment to collaborative work. Over time, the same professionals meet, discussing medical problems of diverse character and both general and more specialised problem solving. Through connecting with the same professionals over time, often discussing the progress of the same patients over days, they are able to follow up on the treatment. Discussing patient flow between levels of care and giving feedback on previously discussed patients also provides the specialists with feedback on their second opinions. Organising VCs as pre-planned meetings allows for situated knowledge, knowledge of the patient, and the opportunity to expand the treatment activity together. This might change the direction of the object so that the practitioners start to use treatment methods and previous knowledge connected to the culture of the specialists.

Acute situations demand general biomedical knowledge according to a specific medical problem in time. The specialist does not have knowledge of the patient in advance or access to other information than what is shared. Here, the use of VC is only available during specific times. This gives an extra hampering factor (as in the context of conformity with pre-planned meetings reported the day before) for use. The medical problem must be evaluated against the ability to wait until the VC connecting time. If it is easier to connect by telephone, the traditional method of discussing medical problems is used. As acute situations cannot be foreseen and cannot wait, the activity is not restricted. Here, it is possible to suggest an alternative for organising VC to discuss acute medical diagnosis. Figure 4 includes a suggestion for organising VC in acute collaborative medical diagnosis as 'unplanned'.

Non-planned acute collaborative work benefits from being organised as a non-planned, 24/7 service. Acute, unplanned collaborative work often brings together different professionals periodically (Figure 4, symbols ☺ ≠), because

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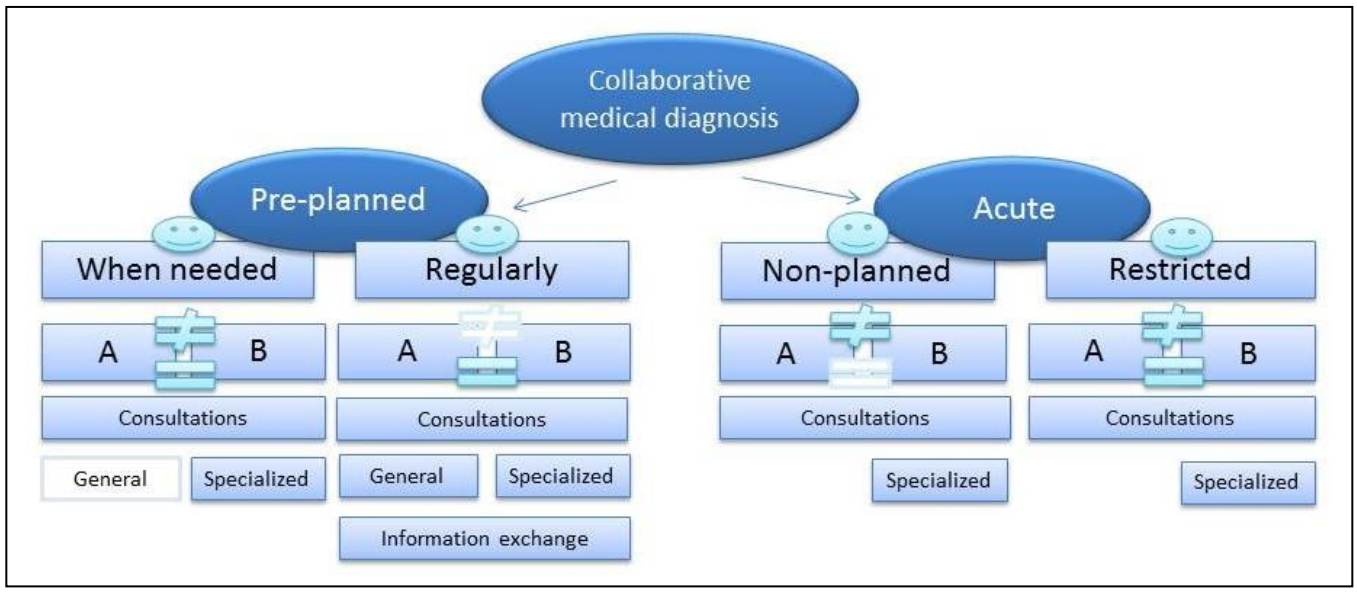

Figure 4. The organisation of VCs for pre-planned and acute situations

the consultations demand different knowledge. Over time, this activity might change the traditional practice, creating this new activity, where the same professionals are able to meet more often. However, it is still not likely that the activity will include, i.e., information exchange, as acute situations demand specialised knowledge and an immediate start of treatment.

VC must be seen as a tool in connection with the context it is a part of. In spontaneous situations, which typically involve discussing the patient only once, the physicians do not have experience with the patient in advance. The organisation and the type of knowledge exchanged (the medical problem) are mutually attached. Connecting using VC regularly allows medical discussions of a more general character, i.e., regularly held meetings including both specialised and more general medical discussions. More general discussions can also be included in pre-planned, as-needed meetings if the same professionals meet over time.

As shown in the framework, knowledge is situated within the activity, context and culture, and it is an interplay between institutional context and organisational structure. How knowledge in daily work practice is structured is established over years, how the practitioners divide their work tasks, the rules for treatment, and the community they locally are a part of this interplay. Introducing VC for collaboration across levels of care calls for awareness of the fact that how the VC is organised and the resources shared must be seen as mutually connected. Neither the use of VC nor the collaborative work itself can be viewed as a transmission of de-contextualized knowledge from one individual to another. A medical diagnosis is the result of a social process through which professionals share a type of knowledge that often includes a treatment method practiced by other practitioners. Therefore, the use of VC also affects the traditional division of labour in health care.

Sharing knowledge leading to changes in working methods and division of labour, creates the contradictions between traditional treatment methods (i.e., referring the patient) and the new work practice. If the purpose of VC is to retain knowledge sharing, the service needs to account for practice as situated knowing so the practitioners know how to continue the activity. Regular collaborative work, including both second opinions and follow-up feedback to those sharing knowledge for treatment advice, should be kept going. This also supports successful use of VC.

VI. CONCLUSION AND FUTURE WORK

The objective of this paper was to outline *how* the organisation of VCs for pre-planned and acute situations affects the content in collaboration. Medical situations are unequal, because the participants who interact in them occupy specialised and situated knowing of the patient and the local contexts. This is often overlooked when implementing new technology, as one solution is developed to cover, i.e., all acute medical situations. Situated knowing of local context demand for adjustment of how VC is organised and how VC is used.

Regularly pre-planned meetings create a practice that includes consultations about general medical problems, specialised problems, and information sharing. Regularity and knowledge of each other and the patient support the sharing of information about patients, as previously discussed. Acute use of VC is organised as a restricted service, offered during a specific timeslot during the day. The consultation is specialised, in which professional(s) with specific specialised knowledge meet. The acute service needs to be a twenty-four-hour service to support the context it appears in, as acute treatment is demanded regardless of time of the day. Restricted time collides with how acute care is organized, as a twenty-four-hour service. VC ‘when needed’, which need to be reported in advance,

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also collides with traditional medical practice, i.e., medical problems need to be solved in the moment. Hence, regular knowledge sharing supports high-frequency use of VC.

Based on this, the paper does not suggest using a universal guideline for how to organise the use of VC. VC is a situated practice, calling for awareness of the fact that how VC is organised affects the frequency of use and the knowledge shared. Even though experience from other similar cases might be used as a normative guideline, the context in which the VC is going to be implemented must be taken into account. As context b illustrates, VCs that fit into the local context (as a part of existing morning meetings) support successful collaborative work.

Unplanned, 24/7 acute use of VC is still left to be explored in the future. The total number of acute medical situations will be affected if the same professionals meet over time and if they are going to follow up on previously treated patients. What is known about the context is that acute knowledge is knowledge in the moment, requiring unplanned access to VC as a tool for sharing knowledge resources twenty-four hours a day.

As time passes, technology improves, while the contexts in which professionals practice continue to be important to its successful use. Also the most advanced technology with the greatest number of applications benefits fitting into daily medical practice to succeed. Today, the availability of electronic health records (EHR) for patients has opened up the sharing of information in consulting with professionals in other areas. Unfortunately, not all hospitals and general practitioners have access to the same systems, and so are not able to access the same EHR at the same time (as in context c in this paper). In contexts a and b, practitioners had access to the same EHR. In context a, pre-checking in the EHR seemed to create more hassle in preparing for the discussions than in context b, where the specialists only relied on the general practitioners to present patient records, without looking them up by themselves. The traditional approach of orally presenting medical cases when discussing them (for example in morning meetings) seems to be fundamental to discussions. Access to pictures and other non-text-based tools in the EHR might enrich discussions, and is an interesting approach to the use of VC that can be explored in future work.

ACKNOWLEDGMENTS

Thanks to the Northern Regional Health Authority for funding the research projects (HST-1021-11-5126 and TFP-506-06) and to all the informants participating in the studies.

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Effects of Telemonitoring on Heart Failure Patients' Quality of Life and Depression Scores: a Randomised Controlled Trial

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***Abstract* — Telemonitoring positively influences some aspects of quality of life. Furthermore it reduces patients' depression and anxiety scores on the short run. The current article presents the results of a one year follow-up study regarding the impact of a first generation telemonitoring system on depression and Quality of Life scores in patients with heart failure.**

Keywords - heart failure; telemonitoring; quality of life; anxiety; depression; type-D personality.

I. INTRODUCTION

Depression and impaired quality of life (QoL) are major problems in patients with heart failure, and exposure to these factors is much higher compared with a community dwelling or age-matched population [1][2][3]. Depression due to a general medical condition is defined as a patient's clinical presentation, which is dominated by a persisting mood disorder, characterized by either or both depressed mood or considerably decreased interest or pleasure in nearly all activities, or a mood that is elevated, expansive or irritable [4]. Also, other cardiac conditions, such as atrial fibrillation, are known to show elevated levels of depression and anxiety [5]. QoL is multidimensional and integrates objective and subjective indicators, a broad range of life domains, and individual values. Dimensions may be categorized in physical, material, social and emotional well being, and activity [6]. Both, depression and poor emotional QoL, can be predicted by Type-D [7][8][9]. Type-D personality is defined as 'the tendency to suppress emotional distress', and is a predictor of long-term mortality in Chronic Heart Disease (CHD), independently of established biomedical risk factors [10].

With the increased application of telemonitoring in heart failure, knowledge about its effects on QoL, and depression becomes highly important. Several telemonitoring studies reported about the impact of telemonitoring on QoL [11][12][13][14], yet limited studies reported about the impact of telemonitoring on depression in patients with heart failure [15][16]. Preliminary results, about the impact on depression, during the first 3 months of the randomized multicentre study discussed in this article (TEHAF-study), showed a tendency to a decreased level of depression [17]. The TEHAF-study primarily focuses on the effects of telemonitoring on heart failure (re)admissions and mortality [18], and cost-effectiveness [19]. Secondary outcomes are: disease specific knowledge, self-care, self-efficacy, adherence, [20] depression, and QoL. It was hypothesized that an intensive follow-up by means of telemonitoring (i.e. the Health Buddy®) improves disease specific knowledge, self-care and self-efficacy, which in turn, positively influences QoL and reduces depression and anxiety.

Several generations of telemonitoring (TM) are known. The Health Buddy® system, used in this study, is a first generation telehealth device, meaning a non-reactive data collection and analysis system. Measurements of interest are collected, and transferred to the care provider asynchronously. It is not a full telemedicine system, and the provider cannot respond immediately to patient data. Second generation systems have a non-immediate analytical or decision-making structure. Data transfer is synchronous, meaning there is some real time processing of patient data. Care providers can recognise important changes in essential measurements, but delays can occur if the systems are only active during office hours. Third generation systems provide constantly analytical and decision-making support. Such systems are used by physician led centers, staffed by specialist nurses, and have full therapeutic authority 24 h per day, seven days per week [21].

The current article presents longitudinal one-year follow-up results regarding the impact of first generation telemonitoring on depression and QoL scores, including the presence of Type-D in patients with heart failure. In the methods section the population, study design, measurement instruments, sample size and data analysis are described. Baseline patient characteristics, prevalence of type D,

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effects on QoL, anxiety and depression, and the relation between QoL, and anxiety and depression are presented in the results part, followed by the discussion, including study limitations, practical implications and conclusion.

II. METHODS

A. Population

To compare telemonitoring with usual care, 870 consecutive patients with heart failure New York Heart Association (NYHA) class II-IV were invited to participate in the TEHAF-study, during their visit at the outpatient clinic of either of three hospitals in the South of the Netherlands, of whom 488 refused or were ineligible (figure 1) flowchart). Patients were asked to fill out several questionnaires during study time [22], and were informed that refusing participation had no consequences for their further treatment. Heart failure was defined as at least, one episode of fluid retention requiring diuretics, either with an echocardiographic left ventricular ejection fraction ≤40% or a preserved ejection fraction with diastolic dysfunction.

Further inclusion criteria were age ≥18 years, capable of providing informed consent, and being treated by a heart-failure nurse together with a cardiologist. Patients were excluded if, operating the telemonitoring device i.e., the Health-Buddy®, was physically or cognitively impracticable; if suffering from Chronic Obstructive Pulmonary Disease (COPD) Gold-classification 3 or 4; if receiving hemodialysis, or in case of a disease with an expectedly shortened life span [22]. Approval was obtained from the Medical Ethical Committee of the participating centers, according to the declaration of Helsinki [23] and written informed consent was obtained before randomization. The TEHAF-study is registered as a clinical randomized controlled trial [24].

B. Study design

From October 2007 until December 2008, 382 patients were enrolled and assigned to a study arm, usual care (UC group) or usual care plus telemonitoring (TM group), using a computer-generated randomization procedure, with stratification per center. Patients of both groups received treatment according to the European guidelines [25], identical oral and written information, and had an easy access to the heart failure nurse. Patients of the UC group four, and patients of the TM group had two planned outpatient clinic visits during follow-up. Moreover, the latter group received a telemonitoring device. The Health Buddy® has a liquid crystal display and four keys and was connected to a landline phone. Every day, a preset dialogue was communicated about symptoms, knowledge and behavior, being answered by touching one of the keys.

Patients' answers were sent via a protected server to the nurses' desktop. Incorrect answers to a knowledge or behavior issue were automatically corrected by the device and visualized in the display, aiming that patients' disease knowledge would increase. Responses were transferred into risk profiles, (low, medium, high) [21] allowing the nurse to quickly identify high-risk patients. A heart failure nurse and a nurse assistant led the process. Positive answers for symptoms triggered immediate responses by the heart failure nurse. The nurse assistant was responsible for educational and general high risks, such as symptoms of depression [21]. To meet with personal specific needs on treatment or education, patients could be allocated to one of the four sets of dialogues with variable emphasis on symptoms or knowledge and behavior [20]. All patients started with the same initial set of dialogues, which was evenly balanced for symptoms and education. After three months the first evaluation of symptoms and education level occurred, with the intention to continue with the best fitting next set of dialogues. Evaluation was based on the number of high-risk alerts during the last 30 days before the end of a program. Beside this, re-allocation to maintain with the best fitting dialogues set was possible at any moment [21]. Following an admission for heart failure, patients were always re-allocated to an intensive symptom monitoring set of dialogues. Monitoring of vital signs was not part of the system.

C. Measurement instruments

Demographic variables (age, gender, race, living situation) and clinical variables NYHA functional class, left ventricular ejection fraction, ischemic heart disease, atrium fibrillation (AF), type-D personality) were measured. This article reports effects on QoL scores, measured by the Kansas City Cardiomyopathy Questionnaire (KCCQ)[26], and depression scores, measured by the Hospital Anxiety and Depression Scale (HADS) [27]. The DS-14 consists of 14 questions, measuring negative affectivity and social inhibition. Scores ranged on a Likert scale from 0-4 points. Type D personality was indicated if both scores were equal or more than 10 points [28]. QoL was measured by the Kansas City Cardiomyopathy Questionnaire (KCCQ). This is a 23-item questionnaire that quantifies physical limitations (question 1), symptoms (frequency [questions 3, 5, 7 and 9], severity [questions 4, 6 and 8] and recent change over time [question 2]), self-efficacy and knowledge (questions 11, 12), social interference (question 16) and QoL (questions 13–15). To facilitate interpretability, two summary scores were developed, the overall summary score (OVS) and clinical summary score (CSS), which are built up from different (sub) scores [25]. The OVS exists of the physical limitation score, total symptom score, quality of life score and the social limitation score; the CSS exists of physical limitation score and the total symptom score. The HADS, measuring anxiety and depression, is a 14 items questionnaire consisting of 7 questions for both, depression and anxiety. Scores are ranged on a 4-points Likert scale, with a total score range between 0-21 points [27]. Cut-off point for anxiety or depression disorder is 10 points and higher.

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D. Sample size

The sample size of the TEHAF-study was built on the number of hospitalizations for heart failure. Expected was a 50% reduction in heart failure admissions [22].

E. Data analysis

Demographic interval and ratio variables were investigated for normality of distribution with the Shapiro-Wilk Normality Test. If normally distributed, means and standard deviations are given. Student-t and Mann-Whitney test is used to estimate differences of baseline variables. Student-t test is also used to assess differences between AF and anxiety and depression scores, and AF and QoL. Categorical variables are presented as frequencies and percentages.

Correlations between type-D, and anxiety and depression scores or QoL, and between anxiety and depression scores and quality of life, were tested by the Pearson correlation test. Chi-square is used to assess differences for type-D personality between the usual care and telemonitoring groups. Student-t test is used to assess differences between type-D personality and QoL and depression. The effects between groups on QoL, and anxiety and depression scores in time (baseline, T3, T6, T12) were assessed with generalized estimating equations analysis (GEE).

GEE was used to correct for the dependency of the observations in time and for the difference of the time periods between the follow-up measurements. A structured covariance matrix was used in the GEE analysis.

TABLE I. BASELINE CHARACTERISTICS

Variable	**N**	**TM group (197)**	**UC group (185)**	***p*-value**
Age (years)	382	71.0 ± 11.9	71.9 ±10.5	0.621
Range*		32-72-91	37-74-93	
≥ 75		88 (45)	85 (46)	0.199
Caucasian race		197	185	
Gender	382			0.747
Male		115 (58)	111 (60)	
Married / partner (yes)	379	122 (62)	123 (66)	0.265
Education	363			0.589
Primary school		63 (33)	59 (34)	
Secondary school /Low vocational training		91 (48)	71 (41)	
Middle Vocational training		19 (10)	23 (13)	
High vocational / university		17 (9)	20 (11)	
History of HF (months)	382	32 ±38	29 ±38	0.413
NYHA-classification / no (%)	382			0.404
NYHA II		110 (56)	109 (59)	
NYHA III		79 (40)	74 (40)	
NYHA IV		8 (4)	2 (1)	
Blood pressure (mmHg)	382			
Systolic		125 ±21.9	128 ±24.0	0.156
Diastolic		72 ±12.5	74 ±12.2	0.193
Heart rate (BPM)	382	77 ±15.1	75 ±13.8	0.252
Left Bundle Branch Block	382	20 (10.2)	22 (11.9)	0.587
Heart rhythm at baseline	382			
Sinus rhythm		96 (48.7)	113 (61.1)	0.015
Atrial fibrillation		62 (31.5)	35 (18.9)	0.007
Pacemaker rhythm		36 (18.3)	35 (18.9)	0.817
Type-D personality	360	67 (36.4)	68 (39.8)	0.358
Charlson index	382	2.6 (±1.5)	2.4 (±1.4)	0.358

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As independent variables three dummy variables for time, group (usual care versus intervention), and interaction effects between group and the dummy variables of time were included. The method of GEE is often used to analyze longitudinal and other correlated response data [29]. GEE takes into account the correlational nature of repeated measures data within subjects, and securing minimal loss of patients due to incomplete data. Data imputation is not executed because when using GEE to analyze a longitudinal dataset, imputation of missing data has no value above non-imputation [29]. Analyses were corrected for baseline differences. To analyze within group effects between baseline and after 12 months regarding QoL, anxiety and depression scores, Wilcoxon non-parametric test was used. SPSS version 18 was used for all data analyses. P-values < 0.05 were considered statistically significant.

III. RESULTS

A. Baseline characterisctics

Three hundred eighty two patients met the criteria, and were allocated to the TM group (197) or to the UC group (185). Patients' mean age was 72 (±11), and 46% were ≥75 years old; 59% were male, 65 % lived with a partner; 57% were in functional class II, 40% in Class III 3% in class IV. Mean left ventricular ejection fraction was 0.38 and 61% were ≤ 0.45; 50% had ischemic heart disease. Study arms were well balanced regarding baseline characteristics (table 1), except for AF. No differences were found for anxiety and depression, or QoL among patients with AF or other heart rhythm. Follow up was incomplete in 81 (21%), 43 in the usual-care and 38 in the intervention arm, due to death (7.8%), increasing physical impairment (6.0%), stress or losing motivation (5%), other (1%) or lost to follow-up (1.2%).

B. Prevalance of type-D personality

Respectively 184 and 176 patients answered the DS-14 questionnaire for the type-D personality. No difference in prevalence of type-D personality was found between the groups. In the TM group 67 (36.4%) and in the UC group 68 (39.8%) of the patients belongs to the category with type-D personality. Overall, no correlation was found between type-D-personality and anxiety (p=0.681, Pearson= -.022) or depression (p=0.443, Pearson=0.041) scores, whereas all dimensions of QoL (p<0.001) were negatively affected by type-D without differences between study groups.

C. Effects on anxiety and depression scores

No difference was found regarding depression prevalence at baseline, with a registration of 42% (79 on186) in the TM group and 41% (69 on 167) in the UC group. A significant difference for anxiety in favour of the TM group was found after 3 and 6 months, irrespective of correction for baseline values (Table 2). However, this effect disappeared after 12 months. For depression a significant different effect was found only after six months in favour of the TM group. After correction for the baseline values, a favourable effect was found during whole follow-up.

Also for anxiety and depression scores, within group differences were calculated among patients completing questionnaires at baseline and after 12 months. After 12 months anxiety was significantly lower in the TM group (p=0.041, Z=2.043), whereas no difference was found for and no difference for anxiety (p=0.229, Z= -1.203).

D. Effects on quality of life

Uncorrected for baseline value, the OVS and the CSS tend to differ between the TM group and the UC group after one year, yet no difference remained after correction for From patients completing the KCCQ-questionnaire at baseline and after 12 months (272) within group differences were calculated. No within group difference was found for the CSS. For OVS significantly higher score was demonstrated in the TM group (p=0.022, Z= -2. 290), whereas no difference was found for the UC group (p=0.790, Z=-.267). QoL, being a sub score of the OVS, showed similar changes, with p= 0.002 (Z= -3.149) compared to p=0.239 (Z= -1.178), respectively for the TM group and the UC group. For the sub-score self-efficacy a significant improvement was found for both groups with p<0.001 and p=0.028, respectively for the TM group and the UC group.

E. Quality of life and depression

For both groups, a negative correlation was found between the sub-score of QoL and depression (p=0.025, Pearson - 115) and QoL and anxiety (p=0.036, Pearson - .107), meaning that the presence of anxiety as well as depression is related to lower QoL. No significant correlation between anxiety and depression scores and OVS or CSS was found.

IV. DISCUSSION

In this study it was found that telemonitoring positively influences depression and anxiety scores, meaning that telemonitored patients were less depressed during whole follow-up, and less anxious at 3 and 6 months after the start of the study. The difference in depression indicates that telemonitoring seems to slightly decrease patients' moods.

Our finding of 42% depressed patients was comparable with the prevalence range of 9% to 54% in a Caucasian population as reported in a recent meta-analysis [3]. Mean depression level of all patients at baseline was slightly higher compared to the preliminary results in 101 patients investigated at 3 months after start of the study. However, the same course is demonstrated for the results after 3 months, being a slight decrease of depression scores in the

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TM group and stable level of depression scores in the UC group [17]. Initially, positive results were found for QoL, yet after correction for baseline differences disappeared.

The effects on the self-efficacy were congruent with the self-efficacy findings described elsewhere [20]. Telemonitoring improves the communication between patient and health care professional; this may result in an increased self-efficacy. The TEHAF-study primarily focused on the effects of telemonitoring on heart failure (re)admissions, mortality, and cost-effectiveness. No significant differences were found for hospitalizations and mortality, yet the number of contacts with the heart failure nurse was significantly lower for patients using telemonitoring. Sub-analysis showed differences for some sub-groups, as living with partner and heart failure duration less than 18 months [18]. No difference between groups was found for costs, however sub-group analyses showed that telemonitoring is more effective in patients with heart failure duration less than 18 months [19]. Also, a significant improvement was found for knowledge and self-care, and for some domains of adherence [20].

Myers [12] performed a non-randomised study with a follow-up time of 2 months and compared the results of 83 telemonitored patients with historical patients receiving usual care. Reported results included pre- and post-test results of the telemonitoring group, measured by the Short Form 36 item health survey (SF-36). They found an improved QoL in seven of the parameters, yet could not determine whether the change was directly related to telemonitoring. The results of the current study may considered to be due to telemonitoring because characteristics of patients were comparable, type-D personality included, and correction for baseline values was performed. Noteworthy in the study of Myers [12] was the relative high number of patients (n=19) not completing the short study in 2 months. Seven patients (37%) withdrew while they were anxious and upset, which is in contrast with our study with a withdrawal rate of 18% during the follow-up of one year. Benatar [11] followed patients for 3 months and compared the outcomes of 216 patients receiving home nurse visits versus nurse telemanagement. QoL was measured with the Minnesota Living with Heart Failure Questionnaire (MLHFQ) and depression with the HADS. They found improved QoL for both groups when compared pre- en post-intervention, yet no differences between groups. This finding implies that telemonitoring has the same effect on QoL as face-to-face contacts between patient and care professional.

Depression scores showed an improvement between groups in favour of the telemonitoring group comparable with our study results. Goldberg e.a. [30] provided 138 patients, with a mean age of 59 years (unpublished standard deviation), for 6 months with a telemonitoring system of the second generation, existing of an electronic scale and individualised questions about symptoms; almost 75% of the patients were in NYHA class III. No significant effects in QoL were measured within groups, however in the telemonitoring group QoL trended towards improvement.

No difference between groups was described. Within 48 hours post discharge, Woodend et al. [31] equipped 121 patients with heart failure with a telemonitoring system. Mean age was 66 (±11) years and most patients were in NYHA class III. The intervention consisted of 3 months video conferencing with a nurse, daily transmission of weight and blood pressure, and periodic transmission of 12-lead electrocardiogram. Measurements were performed at baseline, after 3 and 12 months. Conferences between nurse and patient were more frequent in the first few weeks after discharge. QoL was measured with the SF-36. For both groups QoL improved significantly after one year. Between groups a significant difference in favor of the videoconference group was found after 3 months, disappearing after one year. This may be interpreted as telemonitoring having effects during the monitoring time, yet effects were disappearing on the longer term. This may suggest that patients may continuously need the system to retain the effects on QoL. Unfortunately, authors did not report which care was delivered after the 3 months of videoconference, which in this context is an important issue.

The most principal differences with our study were the post discharge inclusion and the six-year younger mean age which both independently may have influenced the results. Another multi-centre randomised trial is studied [13] with a follow-up of 6 months in 315 patients. Mean age was 76.5 (±7) years and 60% were female. QoL was measured by the SF-36 and the KCCQ. No differences between groups were found for SF-36 neither for the KCCQ. Koehler [32] et al. provided 354 patients, mean age 67 (±10.7) years, with a telemonitoring device of the third generation telehealth and followed them for 24 months. They investigated QoL with the SF-36 questionnaire and depression with the Patient Health Questionnaire 9-item (PHQ9). No effects were found for depression, and an overall benefit was found for one of the QoL subscales, the first being in contrast with our effects on depression. The Whole System Demonstrator telehealth trial [33] included 1,650 patients with COPD, diabetes or heart failure in 365 general practices, in four primary care trusts in the United Kingdom. Patients were followed with second-generation telehealth devices. Measurements were performed at baseline, after 4 and 12 months. QoL was measured by the SF-12 and EQ-5D questionnaires, anxiety by the brief state-trait anxiety inventory (STAI) and depression by the center for epidemiological studies-depression scale CESD-10. Analysing the data, no disease specific distinctions were made. No differences were found for QoL, neither for anxiety or depression scores.

As mentioned earlier, the Health Buddy® system is a telemonitoring system from the first generation. Several devices belonging to the first, second and third generations are discussed above. No structurally improved effects on QoL or depression have been found in studies using higher

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generation devices. Despite this is not the focus of our study, one may remark that the increased possibilities due to the evolution of telemonitoring systems has shown to lack influence regarding the effects on QoL and depression. At the other hand, underutilization of telemonitoring may occur due to a lacking clarity about the best fitting program for individual patients and equally so that the caregivers are lacking experience in using telemonitoring [34].

V. LIMITATIONS

The power of this study was calculated on a reduction of hospitalizations. Therefore, this study may be insufficiently powered to detect differences in QoL. Besides, 21% of our study population did not finish the study. The follow-up time of 12 months may be insufficient to realize improvements in QoL and depression scores. This study was performed to detect differences between groups. If within-group differences were found without significant different between groups, they are not necessarily attributable to the kind of care delivery. The use of standard questions by researchers can lead to "structural bias" and false representation, where the data actually reflect the view of the researcher instead of the participating subject [35][36][37]. Preset answers will not necessarily reflect how people really feel about a subject and in some cases might just be the closest match to preconceived hypotheses. As a consequence, the results of a quantitative questionnaire design may be statistically significant but at risk to be practically insignificant and their clinical relevance may be unclear, especially in aspects as quality of life and depression [35][36][37].

VI. PRACTICAL IMPLICATIONS OF THE STUDY

The Health Buddy® system has shown to reduce anxiety for a short term and to control depression. Therefore, it may be useful to apply telemonitoring to anxious patients to reduce anxiety and to control depression. This may particularly be meaningful for patients waiting for a referral to a professional or a mental health caregiver.

The finding that type-D personality influences QoL resonates the need of defining personality in order to detect it as a risk factor for diminished QoL [13][14][16].

Telemonitoring systems should be improved in their ability to pay attention for anxiety and depression, and integrate in depth dialogues or guidance how to deal with depressive symptoms or anxiety. This may easily enhance the positive effects of telemonitoring and alleviate the burden on patients and their environment, on health care resources and costs.

VII. CONCLUSION

The Health Buddy® system focusing on patients' experiences has proven to be suitable to positively influence some aspects of QoL, to reduce patients' depression and to reduce patients' anxiety scores in the short run. Furthermore, it was found that QoL is negatively affected by the presence of Type-D personality, and that depression and anxiety negatively affect the sub score QoL.

TABLE II. ANXIETY AND DEPRESSION SCORES

		Baseline	**3m**	**6m**	**12m**
Anxiety*					
	UC group (n= 167)	8.26	8.27	8.19	8.04
	TM group (n= 186)	7.93	7.49	7.43	7.63
	P-value	.344	.028	.028	.226
	BL-correct		.041	.053	.65
Depression*					
	UC group (n= 167)	7.11	7.12	7.28	7.66
	TM group (n=186)	6.96	6.44	6.23	6.78
	P-value	.725	.128	.030	.074
	BL-correct		.047	.011	.028

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TABLE III. QUALITY OF LIFE SCORES

		Baseline	**3 m**	**6 m**	**12 m**
Physical limitation (PLS)	UC-group (n=186)	53.9	53.7	53.6	52.4
	TM-group (n=167)	55.8	57.9	57.1	56.5
	P-value	0.533	0.148	0.230	0.189
	BL-correct		0.080	0.187	0.306
Symptom burden score (SBS)	UC-group	66.0	68.9	68.2	66.9
	TM-group	69.0	74.6	72.2	71.8
	P-value	0.233	0.019	0.130	0.076
	BL-correct		0.107	0.314	0.542
Symptom Frequency Score (SFS)	UC-group	64.5	66.6	67.7	66.0
	TM-group	66.5	72.7	69.5	69.3
	P-value	0.460	0.019	0.511	0.253
	BL-correct		0.007	0.923	0.789
Self-efficacy score (SES)	UC-group	75.7	80.5	79.5	79.1
	TM-group	80.9	85.6	86.3	85.0
	P-value	0.018	0.015	0.001	0.010
	BL-correct		0.320	0.122	0.255
Quality of life (QOL)	UC-group	58.6	64.3	63.0	60.9
	TM-group	62.8	67.6	68.5	67.8
	P-value	0.142	0.255	0.059	0.028
	BL-correct		0.997	0.247	0.177
Total symptom score (TST)	UC-group	65.2	67.1	67.9	66.4
	TM-group	67.8	73.6	70.9	70.4
	P-value	0.314	0.014	0.250	0.136
	BL-correct		0.020	0.542	0.619
Social limitation score (SLS)	UC-group	52.7	57.7	55.8	53.7
	TM-group	57.1	62.0	63.1	61.0
	P-value	0.171	0.169	0.025	0.030
	BL-correct		0.685	.0109	0.181
Overall summary score (OVS)	UC-group	57.6	60.7	60.0	58.2
	TM-group	61.0	65.2	64.7	63.8
	P-value	0.174	0.071	0.061	0.037
	BL-correct		0.238	0.164	0.208
Clinical summary score (CSS)	UC-group	59.7	61.7	62.8	62.1
	TM-group	61.9	66.8	66.3	67.4
	P-value	0.365	0.053	0.149	0.057
	BL-correct		0.015	0.303	0.394
OVS=PLS & TST & QOL & SLS					
CSS = PLS & TST					
TST = SFS & SBS					

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Play for Health 2.0: Evolving P4H to a Web Environment Using HTML5 and JavaScript

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***Abstract*— Play for Health (P4H) is a telemedicine service consisting of a telerehabilitation platform to improve cognitive and physical deficits through the use of "serious games" and various videogames controllers. P4H is based on a client-server architecture. Its client-side application was developed in C++ using Ogre3D graphic engine and runs on GNU/Linux. The use of these technologies posed some hardware and software restrictions that were a threat to the continuity of the platform. The birth of HTML5 meant a revolution in the way of creating web applications due to its suitability to develop dynamic and multi-platform applications. The incorporation of HTML5 and JavaScript to P4H supposed a new client-side application that takes advantage of HTML5 features to overcome the limitations and functionalities that P4H had at that moment.**

Keywords - Telerehabilitation; serious gaming; videogame controllers; HTML5; JavaScript.

I. INTRODUCTION

Play for Health (P4H) is an integrated telerehabilitation system offering motor and cognitive training through serious games and multiple interaction devices [1]. P4H was presented at this congress in 2011. It is designed to be deployed at home or in clinical centers, and its philosophy is to rely on commonly available commercial off-the shelf videogame interaction devices (e.g., Kinect, WiiMote, dance mats).

P4H is based on a client-server architecture consisting of a distributed application structure that partitions workload among a provider of the service, called server, and the requesters of this service, called clients. P4H server is remotely accessed by clinicians through a web browser to program customized therapies for patients, assess their progress and adjust training parameters according to the evolution of each patient. P4H client is the application used by the patients to perform their therapies in an easy and intuitive way. The client manages therapies, captures different parameters during the execution of the exercises and sends them to the server.

Before its evolution, P4H client was a standalone application developed with the compiled object-oriented C++ programming language, and used the scene-oriented graphic rendering engine Ogre3D [2]. This standalone application only ran on computers with GNU/Linux Kubuntu distribution installed and presented important limitations.

P4H is a continuously evolving technology and its functionality is constantly being increased in order to cover a wider range of pathologies. Technological advances that allow to reduce deployment costs, to overcome limitations or to help the clinicians in making their decisions are incorporated to P4H.

HTML5 [3] is the fifth revision of the HTML markup language used for structuring and presenting content for the World Wide Web (WWW) and it is a core technology of the Internet. Its emergence has revolutionized web development due to its new tools and capabilities for creating dynamic web applications.

JavaScript [4] is an interpreted computer programming language that is directly executed on a computer without being previously compiled. JavaScript can be inserted into HTML pages and can be executed by all modern web browsers. JavaScript capabilities allow to interact with users, control the browser, communicate asynchronously with a server and alter the document content displayed.

The combination of HTML5 and JavaScript allows creating powerful multi-platform web applications, capable to run in a browser regardless of the hardware and software on the computer where they are executed. The incorporation of these technologies to P4H resulted on P4H 2.0. This is an evolution of P4H which maintains and expands its functionalities and solves many of its limitations.

In this document, P4H is described with special emphasis on the limitations of the client application that jeopardize their survival. Next, P4H 2.0 is presented and how the

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inclusion of HTML5 and JavaScript on the client overcame these limitations. Finally, the conclusion and future work are presented.

II. P4H: STANDALONE MODE

P4H development started in January 2009 under the framework of the strategy designed by Fundació iBit (former name for Fundació Bit) to carry out health processes in the context of rehabilitation using an open and scalable platform based on ICTs.

As a result, it was obtained a client-server telerehabilitation system that provides the services and resources needed to carry out at-home personalized rehabilitation programs, their adaptation to patient's evolution, and their supervision by the therapeutic team.

The client application is a standalone C++ compiled program with an architecture based on plugins in order to be easily extensible to new games and interaction devices. The communication among these plugins is done across a message-oriented bus. The main components of this application are:

- Core: Responsible for managing the essential procedures of the system and organizing the execution of plugins through services.
- Content plugins: They implement multimedia videogames developed jointly by clinical and technical partners, following the "Serious Gaming" [5] philosophy to work on the cognitive component of the rehabilitation process and on patient motivation. Fig. 1 shows a screenshot of one of the videogames included in this client. It consists of doing a puzzle selecting the pieces with the movement of a limb.
- Interaction Method plugins: They allow the patients to interact with the videogames and to work on the physical component of the rehabilitation process.

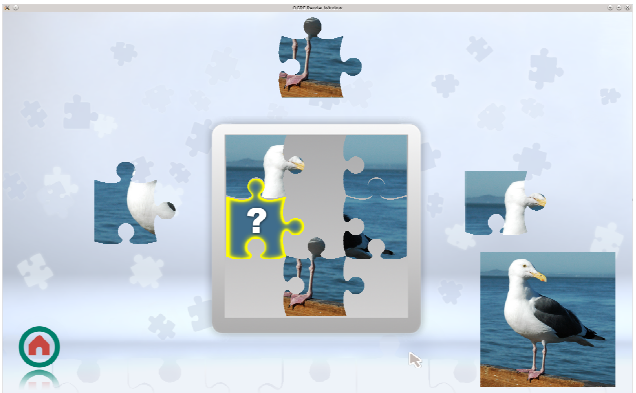

Figure 1. Puzzle videogame's screenshot

The P4H platform also provides a SDK (Software Development Kit), which includes an API (Application Program Interface) for the development of new plugins.

So far, P4H was evaluated in Hospital Son Llàtzer in Mallorca (Spain) [6]. It is also used as a technological base for the exergaming system developed in the project CuPiD (Closed-loop system for personalized and at-home rehabilitation of people with Parkinson's disease) financed by European Union - Seventh Framework Programme [7]. And, for more than 2 years, it has been used in several health centers in Mallorca by more than 100 patients with different pathologies among which stand out Stroke (53 patients), Parkinson Disease (11 patients) and Multiple Sclerosis (9 patients).

With P4H, the intended goal was achieved and it was obtained a low-cost open telerehabilitation system based on the use of videogames, fully developed using open-source software, and capable of interacting with most popular videogame devices.

Despite the good acceptance by the patients and the clinicians, the client application of P4H has some technical limitations that make it difficult to maintain and expand the whole platform:

A. *Dependence on Linux community*

It was decided to work with a stable and widely used Linux distribution, which was easy-to-use and familiar to Microsoft Windows users. Kubuntu, from Canonical Ltd [8], was the distribution that best fitted the project's requirements.

The release every 6 months of a new Kubuntu version became a handicap. It forced us to periodically upgrade the client application, in order to prevent it to become obsolete and keep the system compatible with new hardware products. Every upgrade has required to:

- Upgrade Ogre 3D graphic engine.
- Update dependences with external code libraries.
- Update scripts and internal code.
- Recompile code libraries and troubleshooting.

Kubuntu 12.04 LTS version, with 5 years of support and security updates, is the operating system currently used in order to minimize the impact of these upgrades.

Besides, using code developed by the GNU/Linux community allowed us to reduce the development times, but it increased the time and resources we had to spend correcting errors and adapting that code to the project's needs. These efforts were even greater when we had to update these libraries, replace them because their project was canceled, or upgrade the operating system.

B. *High dependence on hardware*

Ogre3D is a software framework which offers tools that help the developers in tasks such as design, development and representation of videogames providing services as 2D and 3D rendering, sound, artificial intelligence or scenes management, among others. Using this engine has been a key factor to the development of P4H, while it also limited it with its hardware restrictions.

Ogre3D requires a dedicated graphic card NVIDIA Geforce 2, 4 or higher; or an ATI Radeon 7500, 9600 or higher. The lack of manufacturer drivers compatible with the operating system used to run the client application forced us to use non-official drivers. These drivers were sometimes difficult to install, and they turned out not to be fully

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compatible with the graphic cards used, or, sometimes, they did not achieve the required performance from the cards.

Because of that, as well as hardware evolution and the appearance of new technologies (i.e., NVIDIA® Optimus™ for laptops), it was necessary to invest a considerable amount of resources to adapt P4H to these technologies.

Besides, that situation got worse because of the lack of ATI Radeon drivers for Kubuntu 12.04.

Therefore, the range of computers compatible with P4H was severely reduced. That often means an increase of the deployment costs because of the purchase of new computers by the patients.

C. Use of compiled code

When it came to plan and design P4H, compiled programming languages were the ones that best suited the project's requirements. The choice of C++ was determined by Ogre3D engine requirements.

Although the development of P4H would not have been possible without using a compiled language, during the last years, some limitations became evident.

C++ programming language has a slow learning curve, which makes it difficult for new programmers to join the development team.

Once the application is developed, or a new featured is added to it, the debugging, correction, and improvement process is not flexible, and it is time consuming, because of the code complexity and the need of recompiling and reinstalling the application every time.

To make the installation and updating processes faster and more flexible, it was necessary to implement a Debian packages repository. This way, these processes became faster and simpler, and it made it possible to remotely control them. However, the installation and the update of the application can still be too complex for some users, especially when it comes to the installation in patients' homes.

All these technical limitations represent significant costs of development and maintenance that make the system not competitive, and they hinder its growth potential. After analyzing and comparing the costs of continuing with the current client application or shifting to a web environment, we concluded it was more efficient and economical, at medium and long term, to change the technology used in the client application and invest efforts in the development of a new client.

III. P4H 2.0: WEB MODE

P4H 2.0 has been developed throughout year 2013 with the aim of overcoming the limitations of P4H, and making it evolve to a more competitive and transferable system. In particular, they have been pursued the following goals:

- Lower down the deployment costs: In P4H, these costs went from 1500€ to 2000€ per kit depending on the plugins it had to include. Most of the investing was due to the purchase of a TV screen and a computer that met all the hardware requirements. On the other hand, P4H 2.0 runs on a web browser independently of the hardware. This makes the access easier to a greater number of users, and it reduces installation costs, because it can run on patient's own computer.
- Increase the number of pathologies treated: This depends on the number of videogames and interaction methods available in the platform. As mentioned before, in P4H the development of a new videogame or a new interaction method plugin was a tough and resource consuming task. In P4H 2.0, they are used programming and support tools with much less complexity.
- Improve usability: In global terms, the usability of P4H was good and well accepted by a large number of users. However, the installation and updating processes on the client application had some technical difficulties that required a technician to be carried out. On the other hand, P4H 2.0 only needs a web browser.

From a technical point of view, P4H 2.0 keeps the server-side application to manage patients and therapies as well as the plugin-based architecture in the client application to carry out the therapy as in P4H.

Thus, the main difference between both modes is the technology used in the client application. P4H 2.0, instead of a compiled programming language and Ogre3D engine, has been developed using a scripting language such as JavaScript and Cocos2d-HTML5 engine [9].

Cocos2d-HTML5 is the HTML5 version of Cocos2d-x engine [10]. The main reasons to use this engine were:

- It uses JavaScript, HTML5 and Cascading Style Sheets (CSS). This speeds up the development of web applications and eases its maintenance. The use of these technologies allows developing multiplatform applications that only require a compatible web browser.
- It is an active project, well documented and with a wide community of users.
- It is open source under MIT License [11].

A. Content plugins

Resulting of the experience acquired with P4H and the analysis carried out with the medical team, the following videogames classification was established for P4H 2.0:

1) Sequencing: These are games in which the patient has to plan and execute a sequence of tasks to reach a goal. For instance, doing constructions or daily living activities.

2) Memory: In memory games, the patient has to remember sequences of images, sounds or elements positions in order to achieve a goal. For instance, pairing images or repeating a melody.

3) Attention: In these games, the patient has to choose certain elements on the screen according to a selection criterion. For instance, choosing elements depending on their morphology or applying interferences as Stroop effect.

4) Puzzles: When playing these games, the patient has to build a figure by correctly combining their pieces in which it has been split.

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At the moment of writing this paper, 2 videogames have already been developed according to this classification:

- Images: It consists in finding pairs in a board of cards. Fig. 2 shows a game's screenshot with some pairs already matched.
- Colours: It consists in touching objects in a scenario depending on certain selection criteria. Fig. 3 shows a game's screenshot in Go/No-go game mode where the user has to touch the green spots.

Figure 2. Images videogame's screenshot

Figure 3. Colurs videogame's screenshot

Although each videogame has its own gameplay, they have some points in common:

- Difficulty-level-based configuration: Each level consists of a set of parameters with pre-established values. They reduce the amount of time needed to program the therapies, and they allow implementing an automatic level change. Levels have been set after analyzing patients performing the games.
- Reward-based system: These rewards are given to the patient, as he achieves certain goals related to speed, skill or fidelity. The aim of this reward system is to encourage patient's motivation and adhesion to the system
- Parameter recording: During the execution of the therapy activities, a lot of data relating to times, successes, and errors is collected. This data is processed at the client application and sent to the server where it will be stored and delivered to the clinicians in the form of charts.

JavaScript Object Notation (JSON) is used to store the configuration values for the difficulty levels and rewards, as well as to store the recorded parameters and exchange this data with the server.

B. Interaction Method plugins

The key feature of P4H was its capability to integrate and combine different interaction methods and videogames. This allowed for working with the therapies cognitive and physic components independently. Keeping this feature in P4H 2.0 has been a fundamental requisite.

3 different interaction methods have been developed:

- Kinect: For body movements and postures detection using the Microsoft XBox console 3D camera.
- Dance pad: For lower limbs movement detection by detecting the pressure made on the sensitive areas of a dance mat.
- Mouse: For fine movement detection of the upper limbs using a computer mouse.

The main technical difficulty found in P4H 2.0 was the integration of these devices with the videogames that run on a web browser. Especially in the case of the Kinect camera.

To integrate the Kinect camera to the client application, the Zigfu Development Kit (ZDK) [12] has been used to develop the plugin which accesses to OpenNI API [13] through JavaScript calls.

OpenNI (Open Natural Interaction) is an open source framework that provides APIs to develop applications that interacts with the user in a natural way. This framework makes it easier to communicate with devices sensors, such as those of Kinect or ASUS Xtion, and the perception middleware in charge of analyzing and understanding the data collected from the scene through the use of computer vision algorithms.

At low level, all interaction methods must work with native code to be able to communicate with the videogames controllers. This implies the installation of a driver for each of the interaction methods, and it is the only connection between P4H 2.0 and the operating system which it is running on. Drivers for all the developed interaction methods are available for Microsoft Windows 7 or higher.

IV. CONCLUSION AND FUTURE WORK

The main result of this work is an HTML5, CSS and JavaScript application that allows patients to carry out their rehabilitation therapies at home playing videogames on a web browser using different interaction methods.

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Compared to P4H, P4H 2.0 achieved the following goals:

- Make the client application independent of the hardware on which it runs. This has significantly reduced the compatibility restriction of P4H, which implies a considerable decrease of the installation costs and allows more patients to use the application with the computer they already had at home. In these cases the cost of acquisition of the system has been reduced to the cost of the videogame controllers used.
- Open the platform to other operating systems. The execution of the therapies on a web browser makes the application independent of the operating system. This means that we can reach a larger number of users, and that the portability costs to other operating systems are eliminated.
- Simplify videogames and interaction methods development and maintenance. This means a considerable decrease of implementation costs and response times to incidences and modifications.
- Eliminate installation and update processes for the client application. Now the updates are made on the server, and patients only need to access it through their browsers. The only installation the user needs to carry out is the installation of the interaction methods drivers. This installation process is very simple, and it is done once and through a setup assistant. Thus, the installation and update costs have been reduced because it is not required a technician to carry it out at patients homes.

Even though P4H 2.0 is completely developed and operative, it is planned to increase its added value with new games and interaction methods.

At the moment, it is been developed a plan to deploy the system in some health centers of ib-Salut (Public Health Service of the Balearic Islands) as a previous step before its deployment at patients' homes.

ACKNOWLEDGMENT

This work has been funded by the Direcció General d'Innovació i Desenvolupament Tecnològic del Govern de les Illes Balears, a Balearic Islands (Spain) regional government area for promotion of R+D+i.

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The Eve of 3D Printing in Telemedicine: State of the Art and Future Challenges

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***Abstract*—3D printing has raised a lot of attention from fields outside the manufacturing one in the last years. In this paper, we will illustrate some recent advances of 3D printing technology, applied to the field of telemedicine and remote patient care. The potentiality of this technology will be detailed without lab examples. Some crucial aspect such as the regulation of these devices and the need of some standards will also be discussed. The purpose of this paper is to present some of the most promising applications of such technology.**

Keywords*— *3D printing; telemedicine; manufacturing industry; surgery.

I. INTRODUCTION

3D printing technology is changing manufacturing models so fast that traditional industrial processes are chasing this new wave in a way very similar to the paradox described by the ”Red Queen effect” [1]. The first 3D printer was designed as early as in 1984 by Charles W. Hull (see Fig. 1).

Fig. 1: Early version of a 3D printer

However, it is only in the last ten years that the use of 3D printing technology outside the traditional manufacturing environment has started to revolutionize the way we traditionally turn raw materials into functional devices. The growing wave of 3D printing technology has been possible because of two important factors:

- 3D printing technology raised the critical mass that was needed to make manufacturers willing to sell their product to individuals and not solely to private companies.
- the technology started to become available on the World Wide Web making it possible for users to share with one another their recipes to build 3D printings.

Obviously, the two factors are strictly connected in a closed loop: the more new users share their knowledge on building and using 3D printers, the more 3D printers' price will decrease of a magnitude's order. The phenomenon can be seen right now. Following the historical trend, nowadays the mean cost for a home 3D printer is around 3,500 USD while the first ones were of one or two order of magnitude more expensive. Originally built for the manufacturing industry, 3D printers are raising attention also in the biomedical field as a tool for producing biomedical membranes, pills and surgery devices remotely. In particular, the application of such technology is forcing new ways to approach the treatment of a patient both in hospitalization contexts in a laboratory as in home caring. In these notes, we will survey the currently most promising applications of 3D printers with an eye focused on the potentiality of these technologies for the telemedicine applications. The paper is organized as follows: Section II is dedicated to a brief description on how a 3D printer works. Section III will describe some of the most promising use of the 3D printers in the medical field. Section IV will briefly describe the 3D printers communities. The last section will describe some barriers that need to be addressed before a large acceptance of 3D printers in telemedicine could become reality. Some issues related to regulation will be addressed as well.

II. HOW 3D PRINTER WORKS

It is not easy to collect in one single definition all of the technologies involved in the so called 3D print wave. Probably the largest part of the commercial 3D printers can be described as black-box home devices able to create solid objects made from powderer material. The suffix ”printers” in ”3D printers” relies on the fact that, from the user interface perspective, such devices work as common printers in a normal office. The device is connected (using USB) to a PC that codes a design into a series of processes that are sent to the device that outputs the object. The main types of 3D printing processes can be summarized as follows:

1) Extrusion: uses plastic segment of a metal wire that is wound on a coil and unreeled to supply material to an extrusion nozzle.
2) Granular: uses selective fusion of materials in a granular bed. The granules are fused layer by layer until the object is built.
3) Laminated: Laminates objects using layers of thin plastic, paper or metal sheets

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4) Light polymerized: Vat of liquid polymer is repeatedly exposed to light. The exposed liquid polymer hardens in small increments until the model has been built. The remaining liquid polymer is drained from the vat, leaving the solid model. Another system sprays photopolymer materials in ultra-thin layers until the model is completed.

Nevertheless, considering the application filed, this is a very poor definition. Recently, 3D printing was applied to produce highly specialized electronic [2], microfluidic [3] and pneumatic devices [4], [5]. But these are still manufacturing related use of 3D printing technology, where the process involved is basically of physical type meaning that physical know processes are wired into a home usable device. Some major breakthroughs have been presented with the seminal paper by Symes et al. [6] that use a 3D printer for controlling chemical synthesis. They use the Rhino3D package and a low-cost (200 USD) Fab@home robocasting platform to create and control the synthesises and crystallization of two different polyoxometalates using a camera to control the reaction. The most common 3D printers are the ones that use extrusion to create plastic manufactured objects.

III. USE OF 3D PRINTERS IN TELEMEDICINE:RECENT TRENDS

Probably the most interesting use of classical 3D printer in telemedicine application has been enlightened in a recent study [7] presented in the New England Journal of Medicine. This study is particularly interesting because it was the first out-of-the-lab use of a 3D printer in a surgical context. A newborn was diagnosed with Tracheobronchomalacia [8] which is hard to treat and rapidly conduce to airway collapse and respiratory insufficiency. At the age of 20 weeks the baby's trachea was patched with a trachea splint, to allow normal flow ventilation. The splint was created from a biopolymer called polycaprolactone using a 3D printer. The device was created directly from a CT scan of the baby's trachea/bronchus, integrating an image-based computer model with laser-based 3D printing to produce the splint (see Fig 2).

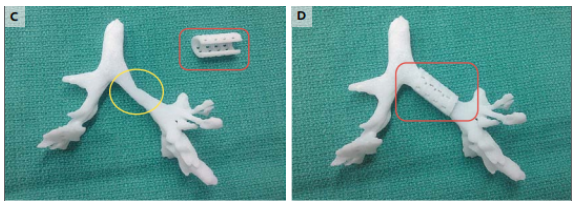

Fig. 2: Tracheal splint and the patched trachea [7] (p. 2044)

This first remote surgery splint creation using 3D printer can be seen as an astonishing potentially new use of 3D printers particularly in development countries where due to the lack of infrastructure for delivery medical prosthesis it is sometime more easy to have Global System for Mobile Communications (GSM) networks availability than fast medical device deliveries. For a strange paradox there are for example African countries where the mobile availability is greater than the available driveways [9], and even countries where telemedicine applications have been delivered successfully, for example in malaria monitoring [10].

One of the most interesting cases has been described by Tam et al. [11]. The surgery involved a 6 year-old girl with a large scapular osteochondroma complicating congenital diaphyseal aclasia. Osteochondroma is a type of benign tumor that consists of cartilage and bone. It is a benign cartilage-capped outgrowth, connected to bone by a stalk. It is the most frequently observed neoplasm of the skeleton. They generally occur at the end of the growth plates of long bones, often at joints. They most commonly form at the shoulder or the knee but have been known to occur in the long bones of the forearm (i.e. the radius and ulna). In this case, the girl had also a congenital diaphyseal aclasia that is a relatively rare abnormal condition that affects the skeletal system. Characterized by multiple exostoses or bony protrusions, it is inherited as a dominant trait. To help clinician visualize a 3D model of the tumor before going in vivo with the patient, a 3D model of the scapula was created by post-processing the Digital Imaging and COmmunications in Medicine (DICOM) image [11]. Nowadays, DICOM files are a well established standard way of manipulating high resolution images of the human body as output of computed tomography or computed radiography [12]. In this case, the 3D printer was used to create a 1:1 3D model of the girl's tumor to help the clinician visualize it and test the procedure to adopt before entering into the operating room (see Fig 3.).

Fig. 3: 3D model of scapula [11] (p. 35)

This first step clearly leads to the other still promising use of this technology, that is, the 3D printing of human tissue for implantation purpose. A living organ, such as a liver or the heart itself, is too complex to reproduce as a single piece outside its connection to the other organs. However, one promising line for 3D printing is the production of human bones [13]. Even if the human bones are a living structure, the fact that some bones replacements like hip replacement are becoming part of the standard surgery methodology for well known clinical protocols in ageing related pathologies [14] has driven research in the area of 3D printers.

In 2011, Anthony Atala [15] took to the stage at the Technology, Entertainment, Design (TED) conference [16] and showed the world a 3D printed kidney. Atala's original 3D printed kidneys were made with a bio-ink that perfectly replicated kidney tissues, the problem was that these tissues were

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not vital (living). Without entering too much into details, the process involved stem cells that have the ability to transform themselves into other cells like nephrons, neurons and cardio muscles' cells. This pluri-potential cells are cultivated in a solution with a structure as support to allow them to aggregate in a structured way. As done in other contexts, the cells were forced to mutate to the desired ones and forced to aggregate in a structured way. The networking relations that exist in a human living kidney were lost. Without the ability to create living organs, 3D printed transplants would remain impossible, even if this step was a great breakthrough, for the potential implications of this technology in everyday life. Even more surprisingly, in 2013 Manoor et al. [17] uses a 3D print to aggregate cells over the geometry of a human ear. The result is quite impressive (see Fig 4.).

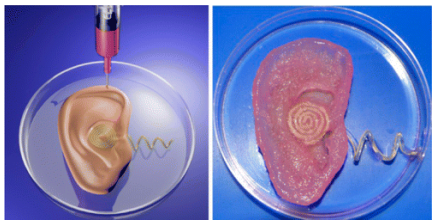

Fig. 4: 3D printed bionic ear [17] (p. 7)

So, even if creating from scratch a fully functional living organ to be used for transplantation purpose is far away from being realized, this first step is quite astonishing. Outside the lab, a goal easier to reach would be the remote creation of prosthesis made by atossic polymer material. Last but not least, another promising approach to the use of 3D printer technology remotely involves the field of pharmacy production. With his seminal paper [6] professor Leroy Cronin demonstrates the possibility to create complex chemical reactions using a modified 3D printer. It was one of the first tries to initiate chemical reactions by printing (i.e. producing) the reagents directly into a 3D reactionwave matrix. Using this approach it is possible to control, with a software, the reactionware design, construction and operation. Another interesting fact is that the whole proof of concept was created using a low-cost 3D printer (approx. 2,000 USD) and open-source design software (see Fig 5).

IV. Online 3D printers community

In the last section, we have seen some of the recent trends in using advanced 3D printing techniques. Obviously, some of them are too complicated and they build materials so difficult to manage that it is not possible to think of them outside a controlled lab environment. Despite this, standardized 3D printing methods using granular plastic material and estrusors to create plastic manufactured object are right now a reality. This technology is so well established that entire web sites like Thinkverse [18] have been created to share the design for the objects to be printed. So, one user can download the design schema for a specific model of 3D printer to build a plastic made object. The community itself in this case follows up the line of the open-source so that every member of the community is supported to share his/her own design with the other community members. Every member

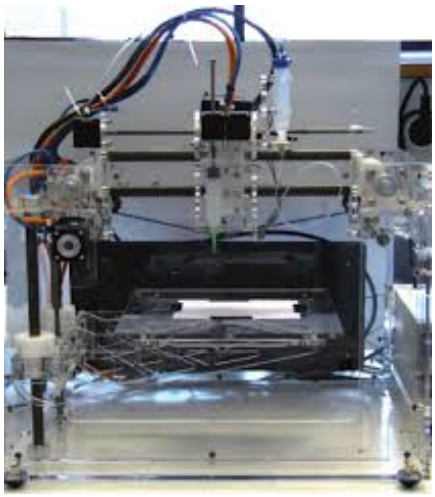

Fig. 5: Open-source design 3D printer

can upload the instruction and design to be downloaded by other users who want to build the object. The revenue for this process is based on the fact that every new recipe and built object is immediately shared between site surfers without any need of registration. This means that every newcomer can build objects without the need of a registration; this step is required only if he/she has new/modified recipes to share. Such communities themselves are now starting to be the object of research [19]. The interaction on these communities is driven in some ways by a hacking spirit.The next step in the area of 3D printer communities will be to go from the pure technical issues to applications in the medical area. These communities will attract researchers, designers and clinicians who want to exchange ideas and experiences from their everyday situations. It becomes clear from the development of 3D printing in the health care that it is vital to keep a viable conversation about hygiene factors, including critical thinking of existing processes, how to handle materials, and so on. Online communities-of-practice for collaborative learning could be about how to produce 3D objects in a safe and hygienic way, according to standardized routines.

V. Future possibilities and the regulation

As usual, when technology is running so fast in a way that has been defined as garage-science, the legislature is in trouble chasing the different fast changes. If one may dream, for example, of a 3D printer for building prothesis for human livings, according to most strict interpretation of the international law, we need not only to guarantee the safeness of the whole production process, but also to ensure sanitary standards that we normally find in hospitals and biomedical manufacturing environments. In the case presented by Zopf et al. [7], we notice also that, before doing the surgery, the clinicians need to have an emergency clearance from the Food and Drug Administration (FDA), being that the polycaprolactone biopolymer does not have consensus to be used by the FDA. The production of medical device inside the US is strictly regulated by the FDA. So, before entering the marketing stage, one medical device needs to be certified by the FDA. However, for a medical device that does not appear in the FDA medical

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device database [20] the use is possible in particular situations [21]. In one case, even though the procedure and the material was not intended to be used on human being, the surgery could take place because it was considered as compassionate cure. Outside this context that is somehow a life risk situation, in normal medical device manufacturing there is both in EU and US a strict regulation that assures the safeness of the product itself both for the patient and for the clinician. In the particular cited case the problem was somehow bypassed by the fact that the nursing process took place in the US territory under the auspices of the same agreed regulation. This leads to a potential interesting law problem, as usual when dealing with remote assistance. If we imagine a remote extrusion 3D printer that uses a polymer to build a splint in a region outside the US, what should be the best way to assure the patient the safeness of the process and to reduce at minimum the risk of rejection by the patient? And upon this, in case something goes wrong, who is the actor being responsible and for what is he/she responsible? As in most of the latest technology breakthroughs, for the moment, the technology wave innovation is leading us to new and unseen possibilities, and not only for the western countries. Once the tide will lower a little, a regulation should be introduced to manage the issues arising from the adoption of this new technology. The time is approaching, because in February 2014, key patents that currently prevent competition in the market for the most advanced and functional 3D printers will expire. When this will happen, when the key patents on 3D printing via laser sintering will expire, we will most likely see a huge drop in the price of these devices. This just happened, when the key patents expired on a more primitive form of 3D printing, known as fused deposition modelling (FDM). The result was an explosion of open-source FDM printers that eventually led to iconic home and hobbyist 3D printer manufacturers. When the medical use of 3D printers becomes widely spread, it is time to initiate conversations about the practitioner's work with 3D printers. Also, systematic evaluations of the use of 3D printers will be beneficial to the area.

ACKNOWLEDGMENT

The first author would like to thank Giuseppe Dalla Motta for his precious discussions on the chemical tasks involved in the industrial 3D printing process.

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Digital WHO Hemoglobin Color Scale: Analysis and Performance

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***Abstract*—Anemia is a public health problem that affects populations in both rich and poor countries. The World Health Organization recommends hemoglobin (Hb) color scale (HCS) to estimate the level of Hb in low resource settings where lab facilities are not available. Our aim is to investigate if the subjectivity associated with the use of HCS in estimating Hb level can be reduced by image processing techniques. It is proposed to take an image of a drop of blood under controlled conditions and then estimate the Hb value of the blood using an image processing algorithm trained on HCS. In the first part of the paper, the protocol for taking the images by a camera is standardized and established. In the second part of the paper, on a set of 20 healthy volunteers, the Hb value of their blood is estimated by the proposed method and compared with their reference Hb value. The correlation between the estimated Hb values and reference Hb values is 0.8. This result on a small dataset is encouraging and shows that color image analysis of blood can be used to estimate Hb.**

Keywords - hemoglobin estimation; color image analysis; WHO HCS; nearest neighbor.

I. INTRODUCTION

Anemia is a condition characterized by inadequate red blood cell volume and a low concentration of hemoglobin (Hb) in the blood. Anemia, which has multiple causes, such as iron deficiency, chronic blood loss, and hemolysis, is a prevalent health problem affecting an estimated 2 billion people, or approximately 30% of the world's population. The most common cause of anemia worldwide is iron deficiency, which is often exacerbated by parasitic infections [1].

In most developing countries, anemia in pregnancy makes a very high contribution to maternal mortality and morbidity. An Hb concentration of < 11.0 g/dl is commonly taken as an indication of anemia in pregnancy. Successful management of anemia in pregnancy depends on accurate and acceptable methods of detecting anemia, assessing its severity and monitoring response to treatment. In pregnant women with mild-to-moderate anemia, timely treatment is likely to prevent the development of more severe anemia and thus reducing the need for blood transfusion which has its own associated risks. Moreover, prevention of severe anemia has direct benefits for both mother and child [2].

A few of the adverse effects of anemia in pregnant women include substantial reduced working capacity, increased susceptibility to infections and prolonged recovery, cardiac complication, respiratory complications, premature births, still births, low birth weight babies and high perinatal mortality. Anemia in children leads to reduced exercise capability, slower growth, impaired neurological and cognitive development, delayed wound healing and increased risk of dying [3].

In absence of lab facilities in a clinical setup, following are the two most common methods for Hb estimation: a) for invasive Hb estimation, the World Health Organization (WHO) Hemoglobin Color Scale (HCS) is a standard tool recommended by the WHO to estimate Hb [4], and b)for the non-invasive Hb estimation, clinicians usually examine the pallor to categorize the level of anemia into three broad categories, viz, mild, moderate and severe [5]. Both approaches require prior training, and suffer from subjectivity associated with the estimation.

Color analysis by digital photography of blood for estimating Hb value has been tried before. Ranganathan and Gunasekaran [6] used a sample of blood, then smeared it on a glass plate to prepare a slide and used color analysis to estimate Hb value using artificial neural networks. They used a standard method designed by them to capture the smeared images. AlZahir and Donker [7] used a novel regression based model for detecting anemia using color microscopic blood images and showed good results in classification of anemia but did not estimate Hb. In this paper, we have extensively studied the behavior of WHOHCS and tried to come up with an algorithm to estimate Hb based on the digital photograph of WHO HCS.

The rest of the paper is organized as follows: In Section II, the WHO HCS and its usage is described. The basic characteristics of HCS when digitized by taking a digital photograph are explained in Section III. The important protocols for taking an image of HCS and a blood sample are established through experimental analysis in Section IV. In Section V, the database and the results of Hb estimation (by the proposed method) on a set of 20 volunteers are discussed. The conclusions of this study, its limitations and the future directions are discussed in Section VI.

II. WHO HCS

WHO's HCS is a simple and effective medical device for accurate estimation of hemoglobin levels at 4, 6, 8, 10, 12 and 14 g/dl, respectively (Figure **1**). WHO HCS has already been validated in a few studies [8][9][10]. The device is simple to use, and the usage process is as follows:

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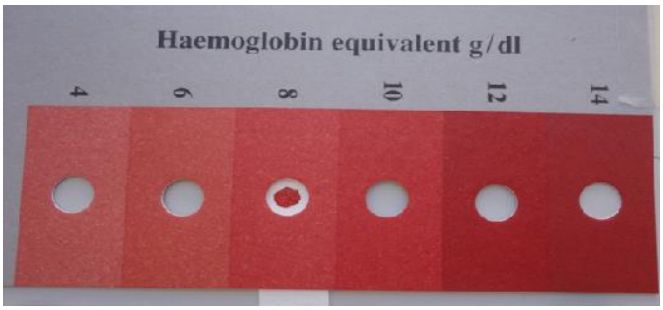

Figure 1. Camera photograph of WHO HCS with blood sample.

- Place a drop of blood on the test strip provided.
- Wait for about 30 seconds.
- Immediately match the color of the stain against all the hues on the scale. The closest match is estimated as the Hb value of the blood.

As shown in Table I, this estimation process indicates whether the patient is anemic, and if so, the severity of anemia in clinical terms. This method of estimating Hb value cannot track minor changes in Hb during treatment, but rather assist in the management of any patient with suspected anemia, for example, to decide whether a patient may require a blood transfusion, a blood count, be referred for laboratory tests or to a hospital or clinic for treatment.

TABLE I. WHO HCS IN CLINICAL TERMS.

Severity of anemia in clinical terms by WHO HCS	
Hb value (gm/dl)	***Severity of anemia***
14	Healthy
12 or more	Not anemic
8-11	Mild to moderate anemia
6-7	Marked anemia
4-5	Severe anemia
Less than 4	Critical

In this paper, we have made an attempt to digitize the WHO HCS, and used it with a digital photograph of a drop of blood to estimate the Hb value of the blood using an image processing algorithm.

III. CHARACTERISTICS OF HCS

Each Hb level image from a scanned image of WHO HCS was cropped to understand whether the clusters of each Hb value are distinct and can be used for predicting the Hb value (of the blood) from an image of a drop of blood taken by a camera.

Figure 2 reveals that Red is most discriminatory at higher Hb levels (14 and 12) whereas Green does a better job in distinguishing lower Hb levels. The histograms of Blue are similar to that of the Green but are less discriminating. RGB color space was considered for image analysis. We also tried HSI (Hue, Saturation, Intensity), YCbCr (Y is luma component, Cb and Cr are the blue-difference and red-difference chroma components), Lab (L is lightness, a and b are the color opponent dimensions) and I1I2I3 (Ohta's color space) color spaces [11] for initial analysis and found that RGB color space gives monotonicity in the Hb levels of WHO HCS. The RGB cube of a scanned image of the HCS is shown in Figure 3. It is clear from the figure that each Hb level forms a distinct cluster and the clusters are orderly arranged such that monotonicity is maintained, that is, clusters of 4, 6, 8, 10, 12 and 14 are arranged such that cluster of 4 is followed by 6, 6 is followed by 8, and so on in the RGB space. The aim was to compute the Euclidean distance between the cluster of blood and cluster of each Hb value, with the assumption that the nearest cluster would be closest to the actual Hb value of the blood.

In the subsequent experiments, we found out that the following factors are responsible for displacement of the clusters obtained from WHO HCS.

- Distance: With the variation of distance between the camera and the HCS, the clusters move such that the monotonicity gets disturbed.
- Resolution: The change in the resolution of the camera from 2 Megapixel (MP) to 14 MP also changes the placement of the clusters.
- Illumination: The monotonicity is disturbed with the variation in illumination.
- Angle: The angle at which the photograph is taken also changes the distance between each cluster and the monotonicity of clusters.

IV. STANDARDISATION OF PROTOCOL

After conducting various experiments with the HCS, we designed a standard protocol where the factors responsible for the movement of the clusters mentioned above are controlled to an extent. We have tried to come up with a standard where the inter cluster distance (ICD) is high and the monotonicity between the different clusters of HCS is maintained.

A. Effect of distance between HCS and camera and resolution of the camera

Images of the HCS were captured from 10 cm, 20 cm, and 30 cm and at a distance from where the camera screen is spanned by the preview of the HCS (approximately 7.5 cm). The megapixels settings of the camera were 2 MP and 5 MP. All the images were captured in natural light. The clusters are plotted in RGB color space (Figure 3) and mean to mean ICD is calculated (Table II). It is observed that the distance of the camera for a linear distribution of the clusters of Hb values should be less than 10 cm. Even at 10 cm, camera with 2 MP fails to maintain the linearity of clusters whereas 5 MP camera just about maintains the linearity with the ICD between Hb values of 8 and 10 being very small. Therefore, a good setting would be a camera distance of around 7.5 cm and the camera's megapixel setting of 5 MP where linearity is maintained and ICD is high.

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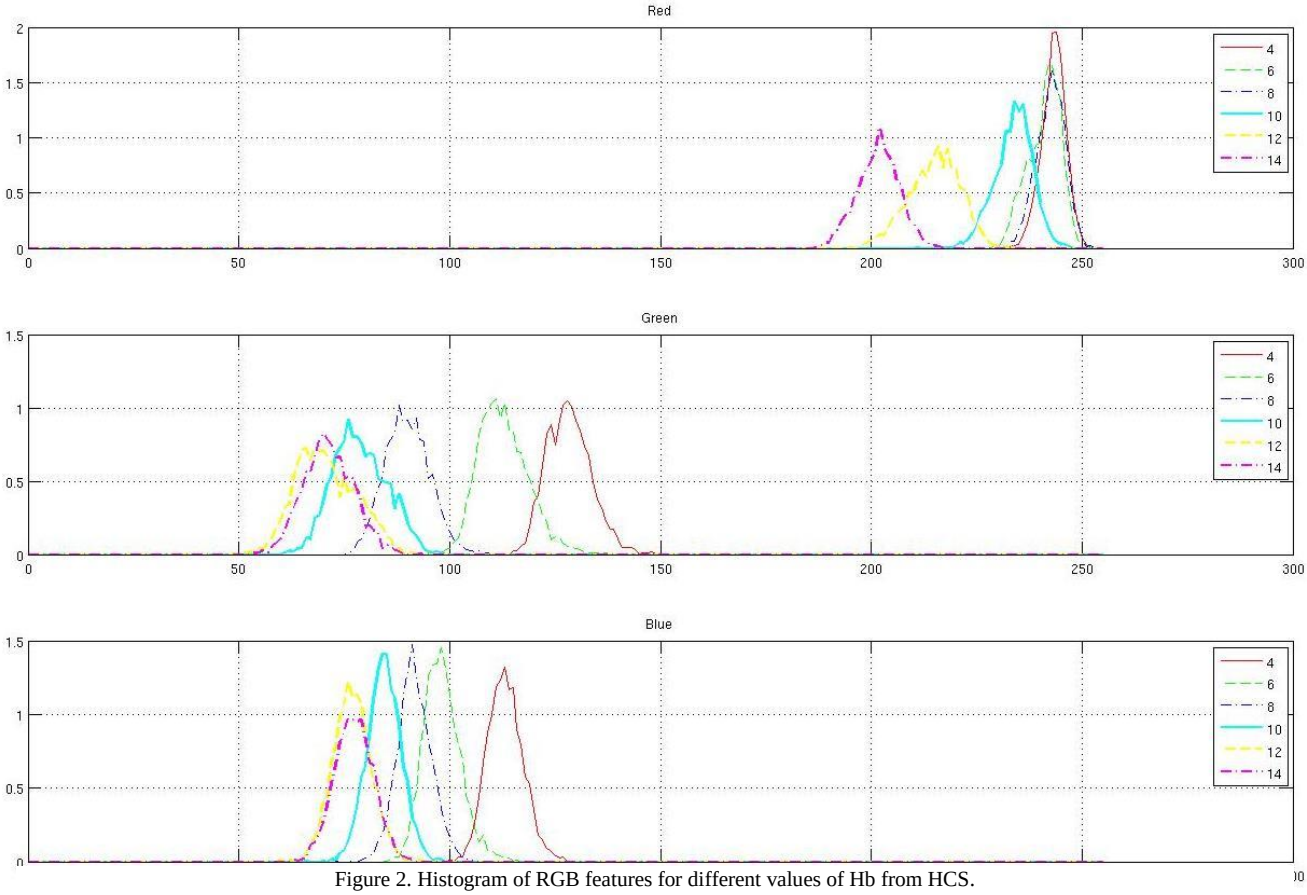

Figure 2. Histogram of RGB features for different values of Hb from HCS.

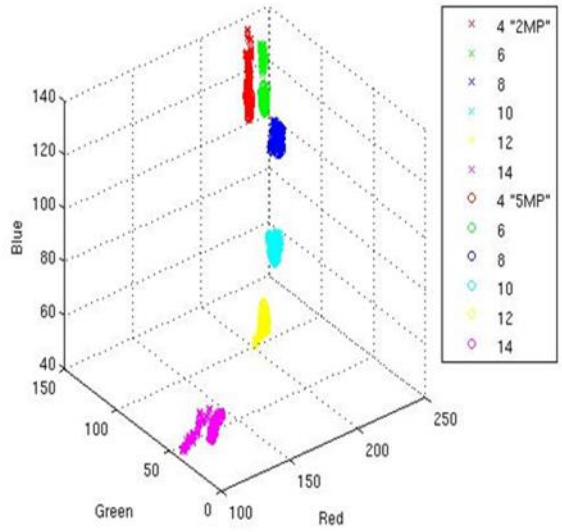

Figure 3. Distance between the camera and the HCS is approximately 7.5 cm (camera screen spans the preview of the HCS). Camera's MP settings are 2 MP and 5 MP.

B. *Effect of Illumination*

In the following experiments, images of HCS were captured by the camera placed at a distance of 7.5 cm and the camera's megapixel setting at 5 MP. All the images were captured in natural light. When taking the photograph, the lux value near the scale was measured. It needs to be noted that it is an adhoc setting where the lux value was not controlled, that is, whatever value was there, it was just recorded. The clusters were plotted in RGB color space and mean to mean ICD is calculated (Table III). Detailed experimentation for different types of light under controlled condition was not conducted. The experiments revealed that in low light conditions (low lux value), the clusters of different Hb values overlap.

Moreover, in low light conditions, the clusters are not ordered according to their Hb values. For example, cluster of Hb value 14 is between the clusters of Hb value 4 and 6. Similarly, the cluster of Hb value 12 is between clusters of Hb value 6 and 8. This change in cluster position is highly undesirable for Hb estimation using WHO HCS. Illumination above 500 lux in natural outdoor light gave high ICD between the clusters of different Hb values of the HCS.

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TABLE II. ICD WITH VARIATION IN CAMERA SETTINGS.

ICD	Resolution – 2 MP and Distance - 7.5 cm					
	4	*6*	*8*	*10*	*12*	*14*
4	0	11.43	31.79	75.16	111.79	170.09
6	11.43	0	34.45	79.35	117.51	177.98
8	31.79	34.45	0	45.04	83.86	147.07
10	75.16	79.35	45.04	0	40.04	107.24
12	111.79	117.51	83.86	40.04	0	69.09
14	170.09	177.98	147.07	107.24	69.09	0
ICD	**Resolution – 2 MP and Distance – 10 cm**					
	4	*6*	*8*	*10*	*12*	*14*
4	0	62.43	131.54	119.55	165.54	204.95
6	62.43	0	69.63[a]	58.77	104.19	146.46
8	131.54	69.63	0	16.95	38.43	88.92
10	119.55	58.77	16.95	0	54.88	105.69
12	165.54	104.19	38.43	54.88	0	52.37
14	204.95	146.46	88.92	105.69	52.37	0
ICD	**Resolution – 2 MP and Distance – 20 cm**					
	4	*6*	*8*	*10*	*12*	*14*
4	0	41.49	112.31	109.2	138.98	139.9
6	41.49	0	72.02	68.82	99.47	102.09
8	112.31	72.02	0	6.19	28.04	34.61
10	109.2	68.82	6.19	0	31.83	38.77
12	138.98	99.47	28.04	31.83	0	14.1
14	139.9	102.09	34.61	38.77	14.1	0
ICD	**Resolution – 5 MP and Distance - 7.5 cm**					
	4	*6*	*8*	*10*	*12*	*14*
4	0	27.49	54.57	87.41	134.85	151.21
6	27.49	0	27.42	60.20	108.21	125.04
8	54.57	27.42	0	33.18	82.39	99.91
10	87.41	60.20	33.18	0	50.11	68.29
12	134.85	108.21	82.39	50.11	0	18.72
14	151.21	125.04	99.91	68.29	18.72	0
ICD	**Resolution – 5 MP and Distance – 10 cm**					
	4	*6*	*8*	*10*	*12*	*14*
4	0	33.81	124.63	134.57	168.39	211.36
6	33.81	0	92.13	101.98	136.89	182
8	124.63	92.13	0	10.72	46.38	97.44
10	134.57	101.98	10.72	0	39.03	91.88
12	168.39	136.89	46.38	39.03	0	53.75
14	211.36	182	97.44	91.88	53.75	0
ICD	**Resolution – 5 MP and Distance – 20 cm**					
	4	*6*	*8*	*10*	*12*	*14*
4	0	25.95	88.06	101.14	129.93	159.42
6	25.95	0	64.26	77.3	107.39	138.21
8	88.06	64.26	0	13.28	43.84	76.4
10	101.14	77.3	13.28	0	32.12	65.59
12	129.93	107.39	43.84	32.12	0	33.81
14	159.42	138.21	76.4	65.59	33.81	0

a. Note that ICD is a symmetric matrix. The second element of the matrix is the distance from mean of the Hb level cluster '4' to the mean of Hb level cluster '6' and so on. The entries underlined in red show change in monotonicity which is reflected in ICD.

C. Angle

For all the above experiments, the HCS was kept right below the camera. So, the angle was fixed at nearly 90°. In order to understand the effect of angle, the images of HCS were captured in the outdoor light at an angle of 60° and 90°. In both the cases, 5 MP camera setting was used and distance for image taken at 90° angle was 7.5 cm. So, the distance between the HCS and the camera would have changed slightly for image taken at 60°.The clusters were plotted in RGB color space and mean to mean ICD is calculated (Table IV). There is a change in linearity between Hb value 8 and Hb value 10 when the HCS is captured at an angle of 60°. Even the ICD has decreased significantly.

TABLE III. ICD WITH VARIATION IN LUX.

ICD	Lux - 136, Resolution – 5 MP and Distance - 7.5 cm					
	4	*6*	*8*	*10*	*12*	*14*
4	0	12.49	22.56	23.41	12.01	23.05
6	12.49	0	14.20	17.25	16.48	32.40
8	22.56	14.20	0	4.60	21.70	41.70
10	23.41	17.25	4.60	0	21.79	42.02
12	12.01	16.48	21.70	21.79	0	20.48
14	23.05	32.40	41.70	42.02	20.48	0
ICD	**Lux - 271, Resolution – 5 MP and Distance - 7.5 cm**					
	4	*6*	*8*	*10*	*12*	*14*
4	0	11.74	25.25	23.26	36.10	49.84
6	11.74	0	15.65	12.87	38.68	55.23
8	25.25	15.65	0	6.31	51.41	69.12
10	23.26	12.87	6.31	0	45.73	63.84
12	36.10	38.68	51.41	45.73	0	19.38
14	49.84	55.23	69.12	63.84	19.38	0
ICD	**Lux - 469, Resolution – 5 MP and Distance - 7.5 cm**					
	4	*6*	*8*	*10*	*12*	*14*
4	0	12.86	29.14	52.90	88.11	104.69
6	12.86	0	17.65	43.68	83.01	101.98
8	29.14	17.65	0	27.94	71.27	92.95
10	52.90	43.68	27.94	0	45.94	70.21
12	88.11	83.01	71.27	45.94	0	26.28
14	104.69	101.98	92.95	70.21	26.28	0
ICD	**Lux - 534, Resolution – 5 MP and Distance - 7.5 cm**					
	4	*6*	*8*	*10*	*12*	*14*
4	0	17.88	37.14	69.21	110.32	131.41
6	17.88	0	20.36	54.76	99.59	124.07
8	37.14	20.36	0	36.44	84.33	112.14
10	69.21	54.76	36.44	0	49.85	81.32
12	110.32	99.59	84.33	49.85	0	35.01
14	131.41	124.07	112.14	81.32	35.01	0

TABLE IV. ICD WITH VARIATION IN ANGLE OF TAKING PHOTOGRAPH.

ICD	Angle - 60°, Resolution – 5 MP and Distance - 7.5 cm					
	4	*6*	*8*	*10*	*12*	*14*
4	0	34.57	88.58	85.99	112.46	114.96
6	34.57	0	54.77	52.37	79.78	83.48
8	88.58	54.77	0	4.17	27.26	34.38
10	85.99	52.37	4.17	0	30.23	37.14
12	112.46	79.78	27.26	30.23	0	10.21
14	114.96	83.48	34.38	37.14	10.21	0
ICD	**Angle - 90°, Resolution – 5 MP and Distance - 7.5 cm**					
	4	*6*	*8*	*10*	*12*	*14*
4	0	27.49	54.57	87.41	134.85	151.21
6	27.49	0	27.42	60.20	108.21	125.04
8	54.57	27.42	0	33.18	82.39	99.91
10	87.41	60.20	33.18	0	50.11	68.29
12	134.85	108.21	82.39	50.11	0	18.72
14	151.21	125.04	99.91	68.29	18.72	0

D. Timing Significance

To understand the importance of time difference between the instance when a blood drop is placed on the strip and the instance when the photo of the blood drop is taken, we did a few experiments directly with the blood. To study whether the RGB values of the blood change with time, the photographs of a blood sample (placed on the filter strip) were taken at 20s, 30s, 40s and 60s after being placed on the

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filter strip. The variation in RGB values of blood with time (30s-60s) was found to be less than 5%.

V. DATABASE AND RESULTS

In a volunteer study, with 5 MP camera setting and distance between HCS and camera being 7.5 cm and HCS right below the camera (Angle - 90°), the image of the blood with the HCS was taken in outdoor light, as shown in Figure 1. The timing of taking photograph was delayed since as per the WHO HCS protocol, the Hb had to be estimated by 2 physicians using WHO HCS after waiting for 30s. The timing of the photograph was kept constant around 60s after the prick (as mentioned in Section Timing Significance, the difference in RGB values between an image taken at 30s and 60s is less than 5%). 20 samples were collected in this volunteer study.

As this was a volunteer study in an office setting, the volunteers had typically high reference Hb values. The Hb value was measured through Sahli's method. The estimation of the Hb value using WHO HCS was done by two physicians and these Hb values were also noted down. It is worth mentioning that HemoCue AB is used as a reference in many Hb studies. However, we could not procure HemoCue AB due to its conflict of interest with Philips. We compared our results with Sahli's method which is widely used in India and many other developing countries such as Indonesia.

A portion of each Hb level and blood sample is cropped from the image for each volunteer. As the scale behavior might have changed for each volunteer due to illumination change, for each image the WHO HCS levels and blood sample were taken for analysis. A part of the database with results is shown in Table V.

TABLE V. THE DATABASE AND RESULTS. THE LAST TWO COLUMNS ARE THE ESTIMATED HB USING OUR APPROACH.

Sahli's method	*Physicians judgment using WHO HCS*		*Average Hb*	*EucRGB*	*EucRGB(interpolated)*
	1	*2*			
12.5	12	12	12.17	12	12.95
10.8	12	10	10.93	10	10.95
10.0	9	11	10.00	12	11.24
9.8	8	9	8.93	10	10.37
12.0	13	12	12.33	12	12.96
9.6	10	11	10.20	10	10.93
9.8	8	10	9.27	10	10.43

In Table V, 'Average Hb' is the average of Hb values by Sahli's and physicians' interpretation of blood sample while using WHO HCS. Since Sahli's method also suffers from subjectivity of human vision and interpretation, we considered the 'Average Hb' for reference; this is expected to reduce the bias and give better estimate as compared to estimate by any of the individual reference method. The last two columns show the results of our approach. The means of the Hb level and blood were plotted in RGB color space, and Euclidean distance measure was used to find the nearest neighbor. The nearest neighbor Hb value in RGB color space for each sample is documented in the column 'EucRGB' of Table V. 'EucRGB(interpolated)' is calculated using the distance of the mean of blood with the Hb values. For example, if the Hb value of blood falls between clusters of Hb value 12 and 14, Euclidean distance between "cluster of Hb value 12 and blood" and "cluster of Hb value 14 and blood" is calculated, and these distances are used for linear interpolation.

'Average Hb' value of each subject and means of red and green channels from the cropped blood sample of each subject (from the image of blood) are plotted in Figure 4. The Hb value for each subject is on the X-axis with mean of Red and Green channels in the Y-axis and Z-axis respectively. Two strong natural clusters are observed suggesting that the Hb value above 12.5 can be easily distinguished from the Hb values below 12.5 by the information present in the red and green channels.

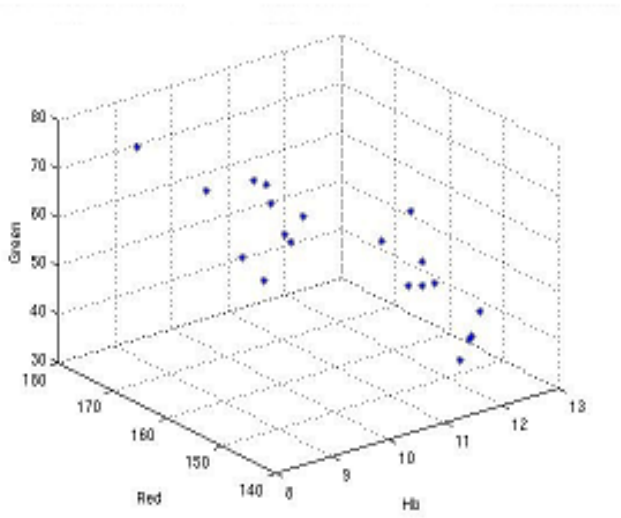

Figure 4. Mean of Red, Green values of only the blood sample images with Hb value(by taking 'Average Hb'). It clearly shows two natural clusters.

Pearson's product-moment correlation coefficient between various methods used in this study to estimate Hb is shown in Table VI. It is observed that the estimation from the algorithm ('EucRGB (interpolated)') has a correlation coefficient of 0.80 with the average Hb value. This is the highest correlation between any of the two methods studied in this paper (the correlation of 0.85 between 'Average Hb' and other methods which were used to derive 'Average Hb' needs to be discounted since it is going to be high by design).

Bland-Altman plots [12] comparing 'Average Hb' value and estimation of algorithm ('EucRGB (interpolated)') is shown in Fig. 5. It shows that the algorithm overestimates the Hb values near 12-13 Hb levels and 10-11 Hb levels, whereas in 10-11 Hb levels the algorithm underestimates Hb values.

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TABLE VI. CORRELATION BETWEEN VARIOUS METHODS OF ESTIMATION AND OUR APPROACH.

Method	Pearson's product-moment correlation coefficient					
	Sahli's	***Physician 1***	***Physician 2***	***Average Hb***	***EucRGB***	**EucRGB (interpolated)**
Sahli's	1	0.54	0.64	0.85	0.46	0.55
Physician 1	0.54	1	0.59	0.85	0.61	0.76
Physician 2	0.64	0.59	1	0.85	0.74	0.73
Average Hb	0.85	0.85	0.85	1	0.70	0.80
EucRGB	0.46	0.61	0.74	0.70	1	0.73
EucRGB(interpolated)	0.55	0.76	0.73	0.80	0.73	1

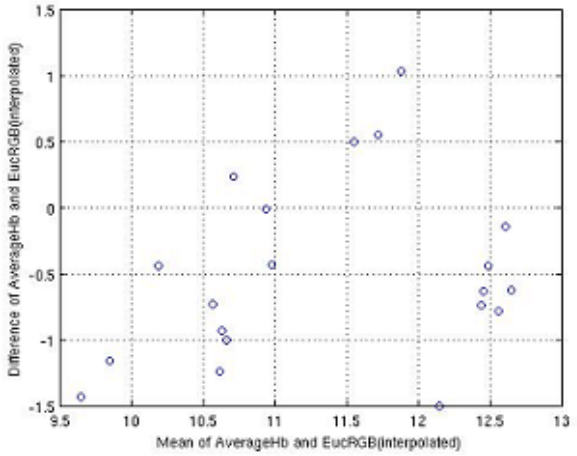

Figure 5. Bland-Altman plots for comparison of 'Average Hb' value and estimation from algorithm ('EucRGB interpolated').

VI. CONCLUSIONS, LIMITATIONS AND FUTURE DIRECTIONS

In this paper, the important protocols for taking an image of HCS and a blood sample for estimating Hb value of the blood are established through experiments. The results show that there is a high correlation (0.8) between color of blood and its Hb value. Though the results are encouraging, the database is limited and has typically high values of Hb.

The three methods (Sahli's and judgment of physicians using WHO HCS) which were used for comparison with the estimate of the algorithm (Tables V and Table VI) have high subjectivity associated with them. So there is a need for an objective measure. In addition, this whole study was conducted in the natural light and there was no control on illumination conditions. Though the results presented in this paper on a small dataset are encouraging, the same results need to be replicated in controlled artificial light to make the system usable anytime and anywhere. One of the methods to achieve this is to mimic natural light using artificial lights.

Despite all attempts to standardize the protocol of data collection, there were illumination changes in the outdoor condition. This might have affected the RGB values of the blood samples. Gray balancing and various other color constancy algorithms in computer vision can be applied to improve the performance of the algorithm.

Fig. 4 suggests that the image of the blood sample on the filter strip (without validation of observation through WHO HCS) is enough and can be used to estimate the Hb value by using machine learning algorithms. However, we need a much larger dataset to develop this data driven approach.

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Remote Camera-based Pulse Oximetry

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***Abstract*—The oxygen concentration in the blood is a very important physiological parameter. This variable is ordinarily monitored using a pulse oximeter, a device that measures the proportion of Hemoglobin that carries oxygen. Although noninvasive, this device needs constant contact with the patient's skin. The possibility of performing the same measurement without contact using a color camera and ambient light is investigated in this work. Particularly, the presence of signals necessary to oximetry measurement on recorded videos is evaluated. It was found that photo-plethysmographic signals are present at two color channels simultaneously, depending on the analyzed region of the videos. Thus, remote camera-based oximetry is possible in principle. Such a device could find numerous applications for patient monitoring, either at the hospital or at home.**

Keywords-pulse oximetry; contactless; camera; SpO2.

I. INTRODUCTION

Among the physiological parameters of interest for patient monitoring, blood gases' concentration is of particular importance. Patient's oxygenation status is a key factor and should be followed closely by the physician in several cases. This parameter is ordinarily measured by a *pulse oximeter* [1]. This device is a low-cost, noninvasive instrument that measures the peripheral oxygen saturation (S_pO_2) and provides an approximation to the arterial oxygen saturation. The later is the ratio between the amount of oxygen-carrying hemoglobin (oxyhemoglobin, HbO_2) and the total hemoglobin content, which includes HbO_2 and oxygen-free hemoglobin (deoxyhemoglobin, Hb), in the arterial blood. Although reliable and small, the pulse oximeter needs constant contact with the patient's skin, usually on the finger tip or the ear lobe, and is prone to movement artifacts [1].

One interesting alternative method to perform pulse oximetry, if possible, would be the use of a simple camera remotely filming the patient. Such a method would greatly simplify the monitoring of S_pO_2 at the hospital, and could be used to reduce patient discomfort due to the use of sensors in applications that require data acquisition during sleep, such as screening for Sleep Apnea Syndrome [2] and automatic sleep staging [3].

Recent literature provides some insight on whether such approach is possible. First, some results show that the acquisition of photo-plethysmography, one of the key ingredients of pulse oximetry, is possible via simple cameras. In [4], consumer level digital cameras were used to record facial-area videos of human subjects trying to maintain static positions under ambient light. A signal with a strong component corresponding to the subject's heart rate was reliably recovered by using spatial averaging over selected regions of interest (ROIs), usually on the green channel. The authors conclude that this signal is mostly due to a variation in volume of sub-cutaneous blood vessels and thus a real photo-plethysmography (PPG). Similar results were found in [5]. In [6], automatic face tracking was used to provide a ROI on each video frame to take care of subject movement. To further improve the response to movement artifacts, the authors used a technique of blind source separation to extract a heart related signal.

Another type of result regarding the second necessary ingredient to pulse oximetry — multi-wavelength measurement — has also been reported. In [7], a camera was used in a special illumination setup where all ambient light was blocked and the subject's arm was illuminated with monochromatic light. Up to three different wavelengths were used, however not simultaneously, and videos were recorded. Oscillations at the heart rate were observed at all tested wavelengths. Simultaneous PPG measurement in two wavelengths was obtained in [8], although with a controlled light source synchronized with the camera. In [9], a mobile phone camera was used to actually estimate S_pO_2, but the camera needed to stay in contact with the subject's skin.

For the oximetry camera to be possible, two conditions must be attained at the same time: remote PPG measurement *and* multiple wavelength measurement, both under normal ambient light. The aim of present study is to verify whether these are possible. This work in progress, once completed will, hopefully, construct a pulse oximetry camera or show its feasibility.

This contribution is organized as follows. Section II summarizes the theory behind pulse oximetry and shows how a camera could be used to acquire the necessary data. Section III describes the experimental setup used and the first results obtained. Finally, Section IV discusses the results and presents some perspectives.

II. PULSE OXIMETRY

A good review of the theory of pulse oximetry is provided in [1]. The interested reader is referred to that work, and references therein, should he or she desire a more detailed explanation. Here a short summary is included for sake of completeness.

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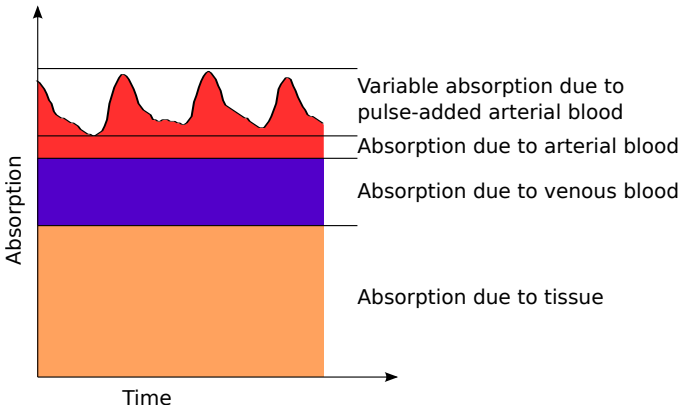

Figure 1. Light absorption in living tissue. Adapted from [1].

The physical principle used in oximetry is the different optical absorption spectra of Hb and HbO_2. This is responsible for the difference in color between oxygenated and deoxygenated blood. The absorption of light passing by a solution at a specific wavelength depends on the path length of the light, the concentration of the solute and a characteristic of the later called *molar absorptivity*. Under a few assumptions, the proportion of the concentration of one solute with respect to another in a two-solute solution can be determined by absorption measurements in two wavelengths. The wavelengths usually used correspond the red and infrared lights. However, any two wavelengths for which HB and HbO_2 have different absorptivity can in principle be used. This method can be used to measure the oxygen saturation of a blood sample. However, when such method is applied to measure oxygen saturation noninvasively in a patient, for instance by shining light through some part of the patient's body and measuring the transmitted or the reflected light, the unknown optical characteristics of the patient's tissues make the calibration of the instrument very difficult.

An interesting approach was proposed by [10] and [11]. The light traveling through live human tissue have a time-varying component in its absorbance signal. This time-varying signal is called photo-plethysmography (PPG) and is caused by the change of volume of the blood vessels related to the cardiac contraction. The higher pressure during cardiac systole corresponds to a larger volume of the arteries and, hence, to a greater absorption due to the increased volume of blood. The situation is reversed during diastole. This is depicted in Figure 1.

The optical characteristics of tissue are represented by the lower part of the graphic. Albeit unknown, the tissue's absorption can be considered constant during short periods. The same is valid for the venous blood's absorption. The variable part of the signal is due mostly to the change in volume of arterial blood. If the absorption is considered additive, one can use the variable signal to perform a normalization and take into account only the contribution of the arterial blood. This provides two advantages. First, only arterial blood saturation is measured, which is the physiological parameter of interest. Second, calibration is easier since only the blood's optical characteristics impact the measure, instead of the subject's tissue.

The normalization is usually performed by dividing the pulsating part of the PPG signal (commonly referred as the *AC* part) by the non pulsating part (the *DC* part). The normalization is performed for each wavelength, yielding two normalized measurement signals, one for the red light and one for the infrared. The ratio between these signals is then used to compute the oxygen saturation. In this later step, an empirical calibration table is used in order to compute the actual saturation.

The pulse oximetry requires, therefore, two "ingredients". First, at least two distinct wavelengths have to be used where Hb and HbO_2 have different absorptivities. Second, an oscillatory signal corresponding to the change in volume of the arteries must be present at both wavelengths.

A. *Camera-based pulse oximetry*

Color cameras, even simple webcams, are devices capable of acquiring a large amount of data. For instance, an webcam with a resolution of 640x480 pixels recording at 30 frames per second will measure light at 307200 different locations (each pixel) at 3 different wavelengths (red, green and blue) 30 times each second.

A camera-based pulse oximeter would use a camera to measure the light that comes from the subject in a similar manner that a regular pulse oximeter uses discrete phototransistors or photodiodes as photodetectors. A camera pointed at a subject from some distance away in a place where enough normal ambient light is present is comparable to a reflectance pulse oximeter. The hardware of the later consists of at least two light emitting diodes (LEDs), one for red and one for infrared, and one or more photodetectors. Both LEDs and photodetectors are packed together in a way that their active sides point at the same direction. When the device is placed in contact with the subject, the LEDs illuminate the subject's skin and the photodetectors measure the reflected light. The camera's pixels play the role of the photodetectors and the broad-spectrum ambient light combined with the color filters in the camera provide the measurement at different wavelengths.

In order for such a camera-based oximeter to be feasible, it remains to be verified that both "ingredients" for pulse oximetry are present. Multi-wavelength measurement is already a feature of color cameras. What remains to be verified is that a reasonably clear PPG signal can be acquired in at least two color channels simultaneously. That is the objective of this work.

III. Experimental setup and initial results

The experimental setup carried out was as simple as possible. Videos of human adult subjects were recorded, one subject per video. During recording, the subject was in a sitting position facing the camera, while trying to remain static. The camera imaged the frontal part of the subject's face from about 40cm away. The illumination was composed of natural daylight and the regular fluorescent ceiling lamps already present at the office. The camera used was an of-the-shelf consumer webcam (HD Webcam Citrine WC064, Sweex Europe B.V., Netherlands). It can record color videos at 640x480 pixels resolution and at 30 frames per second.

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This setup mimics what would be a possible arrangement for a future camera-based pulse oximeter. For instance, a patient would be lying on a hospital bed in a illuminated room. The camera of the pulse oximeter would be pointed to the patient's face, as this part is likely to present uncovered skin. The oximeter would be at some distance away from the patient, possibly at the ceiling, and would measure the S_pO_2 without encumbering the patient with a contact sensor. The actual distance from the camera to the patient should not be critical provided adequate optics are used, as a longer distance from the camera to the patient can be compensated with a longer focal length. What is important is that a sufficiently large part of patient's skin is visible from the camera's point of view.

Several videos of about one minute in length were recorded. In order to avoid any disturbance, each video was stored in raw format (YUV422)[12] in an AVI[13] container file. This is important because most video compression techniques lose information. Since the PPG signal is not usually seen with the naked eye, a video compression algorithm could, in theory, cause an important damage to the acquired PPG signal while maintaining the perceived quality of the compressed video. The drawback of recording raw video is the large size of the video file. An one-minute raw video file has a size of about 1.2 GiB. However, this difficulty is particular of the experimental protocol used and is should not be present in the final device since the later should process the video signal in real time and will have no need to record the video.

Video recording was done with MPlayer[14] in a PC running GNU/Linux.

Video processing was made in Python[15] using the OpenCV library[16] and custom made code. The Python language was chosen due to its simplicity that allowed a fast application development. As in [4], spatial averaging was used to improve the signal-to-noise ratio (SNR). Each color of each pixel has a relatively low amplitude resolution of 8 bits, which leads to a poor SNR. This can be partially overcome by averaging together neighboring pixels in a region of a frame. In this work, each frame was divided in 20x20 pixel regions that where averaged together in each color channel. This provided a single value per region, per channel and per frame. The channel time series of the regions were later analyzed looking for the presence of PPG signals.

A. Results

Figure 2 shows parts of two videos. These images where created by averaging the green channel over the entire video for illustration purposes. The subject on the left shows considerable movement while the one on the right was able to keep a more static position. Superimposed on the images are the grids formed by the 20x20-pixel regions.

Three regions in Figure 2 are indicated by letters, two on the left image and one on the right image. The time series corresponding to the region "A" are shown in Figure 3. All time series show an increasing trend, probably related to the subject's movement during the recording. On the green channel, two oscillatory components are visible, one with a low frequency and one with a relatively higher frequency. The low frequency component is possibly related with the subject's

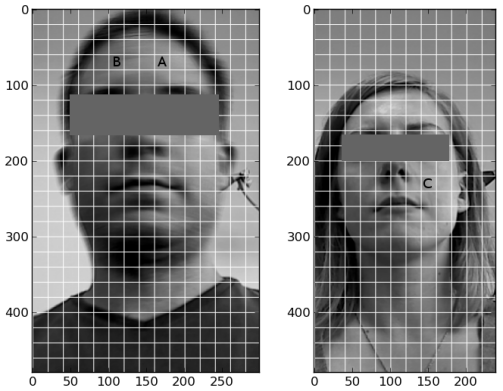

Figure 2. Images formed by averaging the green channel of all frames together. Overlaid are grids of 20x20 pixels. Units shown are in pixels.

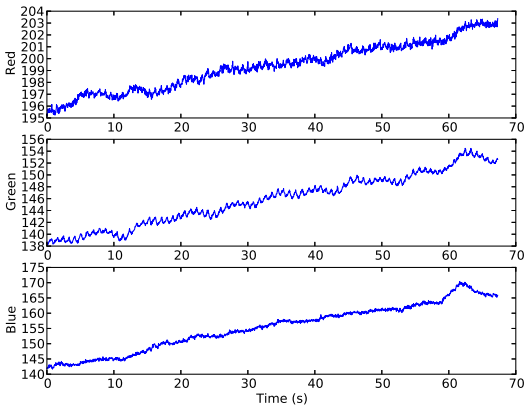

Figure 3. Time series corresponding to the region "A" in Figure 2.

respiration. The high frequency component is the PPG signal. Its presence on the green channel is in according to what was found in [4]. The red channel, on the other hand, shows what appears to be a PPG signal, although with a lower SNR. The blue channel does not seem to have a PPG signal.

In order to better evaluate the possible presence of the PPG signal, the time series were band-pass filtered with a FIR filter with cut-off frequencies at 0.7 Hz and 2.5 Hz. The filtered signals are shown in Figure 4. The PPG signal is easily seen on the green channel. Even a slight amplitude modulation is present, also possibly related with respiration. On the red channel, the PPG signal can also be seen, particularly between 15 s and 40 s and around the 60 s mark. The signal quality is, nevertheless, worse.

The presence of a PPG signal in multiple channels is very dependent on the particular region chosen. As an example, the band-pass filtered time series of region "B" are shown in Figure 5. Although clearly seen on the green channel, the PPG signal is absent from the other channels.

Finally, different subjects may have different "optimal" face regions where the presence of PPG is concerned. The filtered time-series of region "C" on the second subject are

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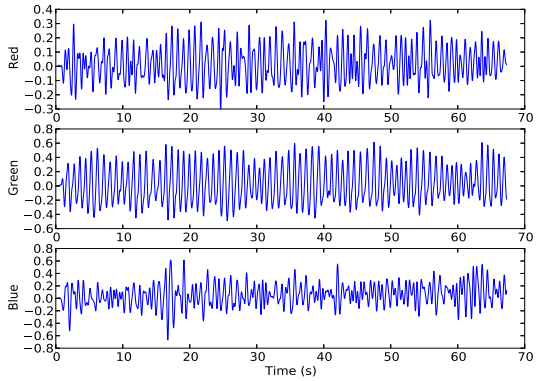

Figure 4. Band-pass filtered time series of region “A”.

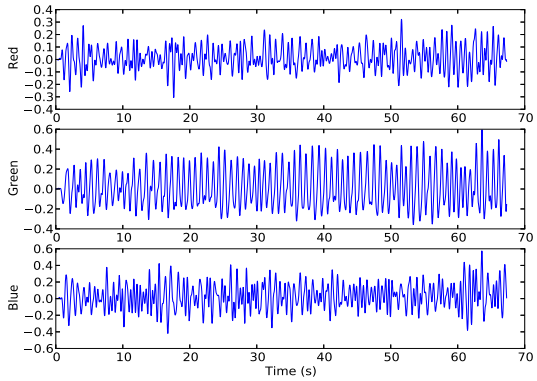

Figure 5. Band-pass filtered time series of region “B”.

shown in Figure 6. A strong PPG signal is present on both red and green channels.

IV. Discussion and Conclusion

The possibility of remote oximetry measurement via color camera and ambient light was investigated in this work. It was found that a necessary condition for pulse oximetry, namely the acquisition of PPG signals simultaneously in more than one wavelength, was present in the recorded videos with at least two different human subjects. The simultaneous presence of PPG signals in multiple wavelengths was not verified in previous publications under the conditions of this work (non-contact camera, ambient light). This positive result means that remote, camera-based pulse oximetry is in principle possible.

However, a lot of work remains to be done before such a device is constructed. First, systematic measurement of the recovered PPG amplitude for all face regions must be made. This will help with the development of the next necessary step that is an automatic and reliable way to detect and extract the PPG signals. To this end, tools from the computer vision domain may prove invaluable. After such extraction tool is devised, a further step would be to create an experimental protocol where different subjects are recorded while using standard pulse oximeters and breathing at different oxygen concentrations to provide a data base that would allow for

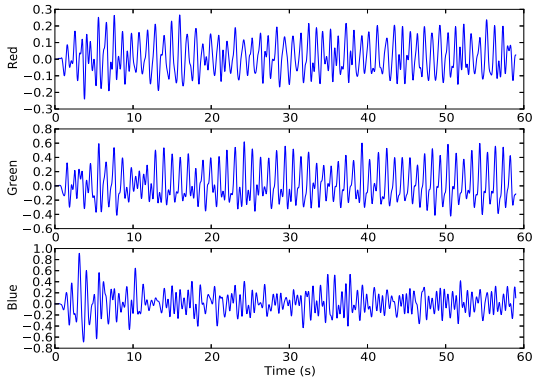

Figure 6. Band-pass filtered time series of region “C”.

calibration of the camera oximetry.

The possible applications of camera-based remote pulse oximetry are numerous. At one end, long-term hospital and home monitoring could replace contact oximeters in order to decrease patient discomfort. On the other end, novel and disruptive applications may become possible. For instance, a simple software application could transform a smartphone into a medical device capable to measure an important physiological parameter without any hardware modification and allow for screening or monitoring of several diseases at home.

Acknowledgment

The author would like to thank ADIR Association for its support in this work.

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Telememonitoring in Cystic Fibrosis: Treatment's Adherence and Economical Evaluation in a Period of Three Years

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***Abstract*—We examined data related to Adherence to telemonitoring in our Cystic Fibrosis patients followed at home for a period of 3 years. We tested the possible presence of a saving for Italian National Health Service. We kept electronic records of transmissions, in spreadsheet format. For each transmission, the main parameters and any action taken were collected. A summary of the activities was carried out automatically. A monthly average percentage of Adherence to prescribed frequency of transmissions is calculated. We performed an economic analysis of the costs for patients followed at home by telemonitoring, recalled under suspicion of acute pulmonary recurrence. We received, from February, 15 2010 to May, 31 2013, 2097 data transmissions overall. The average compliance in the reporting period was 28,86%, with increasing trend. We calculated a saving compared to traditional home care of € 5.320,33 /year/patient. We conclude that the improvement of outcome in FC necessarily passes through an improvement of the Adherence to treatment. The presence of an economic advantage is once again, although not significant. More controlled psychological and behavioral studies are needed to establish the real long-term effectiveness of the use of Telehomecare in CF.**

Keywords-telemedicine; telemonitoring; cystic fibrosis; economic evaluation.

I. INTRODUCTION

In Cystic Fibrosis (CF), the natural history is characterized by recurrent episodes of respiratory infection that causes a progressive pulmonary damage, with decay of long-term lung function leading to death [1].

Spirometry shows over time in these subjects a reduction in forced expiratory volume in the first second (FEV1), and then also a reduction in Current Volume (FVC), which is around 2% of the expected value every year [2].

In case of pulmonary exacerbation, an early initiation of antibiotic treatment helps to prevent the development of more serious complications limiting consequently also the pulmonary damage in the long term. Early interventions also allow us to use advantageously less invasive antibiotic therapies, even using the oral route of administration [3].

Since 2001, in the CF Centre of the Pediatric Hospital Bambino Gesù in Rome, we started to use Telehomecare (THC) in the follow-up of our patients at home. The first results of this work have been encouraging. We found a statistically significant reduction in hospital admissions and a tendency over time towards a better stability of the respiratory function [4].

It is known that, from a psychological point of view, telemedicine can help to improve the outcome through the acquisition of a better awareness of the disease and of the therapeutic program by the patient [5]. In our experience, the outcome improvement in the follow-up in CF necessarily passes through improving adherence to treatment [6].

Regarding the economic aspect, definitive studies on a possible positive role of telemedicine in the rationalization of hospitalization related to long-term follow-up in CF are lacking to date.

We have attempted to quantify the costs of telemedicine in the follow-up of our patients. In an initial feasibility study [7], we calculated a possible annual saving of € 5241 for each CF patient.

In a subsequent study, conducted "in the field" [8], we performed an economic analysis of the costs for 19 CF patients followed at home with remote monitoring for a period of 2 years. We analyzed the actual costs incurred by Italian National Health Service (INHS) every time they have been called to the hospital for suspicion of a respiratory exacerbation. We calculated a total saving, compared to the traditional method without telehomecare, of € 132,144.91 in 24 months, corresponding to € 3,303.62 / year / patient. The presence of an economic advantage for INHS is then also confirmed, although the amount of the saving is not large, relatively to the total costs. Data from the study encourage a possible role of telemedicine in the organization of home care of patients with CF. In the present study, we examined the clinical and economic data related to the activities of telemonitoring on behalf of our CF patients followed at home for a period of 3 years, in order to better understand the evolution of clinical trends and the evolution of the economic in time.

The paper is structured as follows. Section II discusses the methods used for our approach. Section III presents the results, followed by a discussion, in Section IV. We end with a conclusion and ideas for future work.

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II. METHODS

This is a case feasibility study on using telehomecare for cystic fibrosis follow-up.

24 patients are currently included in the THC program.

A clinical diagnosis of CF was given in all subjects, confirmed by study of the CFTR gene and the sweat test. Patients included in THC program are still followed and treated with the usual protocols of follow-up, similar to those who do not practice [9].

We used Spirotel ™ instrumentation, which provides and transmits remotely data from Spirometry and overnight pulse oximetry. The working method was described and discussed in a previous study [10].

Since February 2010, we started keeping an electronic register, in spreadsheet format. For each transmission, the main parameters and the measures are recorded. A monthly statement of assets and the calculation of the average percentage of Adherence to the recommended frequency of transmissions (defined as the ratio transmissions / total patient days) is automatically done.

We also quantified the actual costs associated with the use of telehomecare in the follow-up of patients. We have considered as costs all the hospital admissions (Day and Ordinary), the cycles of therapy at home and the rent for the telemedicine equipments. We have considered as revenues the incomings from the use of the available beds and the working days retrieved.

We formulated the hypothesis that, without telehomecare, each recall would have resulted in hospitalization for the necessary clinical test and any treatment. To evaluate the possibility of an economic benefit from the use of THC, in order to rationalize hospital admissions, we compared the actual costs incurred by INHS with the costs that would be sustained if each recall had resulted in hospitalization.

III. RESULTS

The data are related to the activity carried out in the period from February, 15 2010 to May, 31 2013.

We enrolled in THC a total of 39 patients. 15 dropped out (38,46%), 9 for poor adherence (60%), 4 because they died (26,67%), 2 for other causes (13,33%) (Table I).

TABLE I. BALANCE OF ENROLMENT

Patients	**n.**	**%**
enrolled	39	
active	24	61,54
drop-out	15	38,46
poor adherence	9	60,00
died	4	26,67
other	2	13,33

We followed an average of 28 patients during this period.

We received 2,097 transmissions containing 2766 Spirometry and 706 Pulse Oximetry. Since April 2011 we received 1031 questionnaires regarding symptoms. We carried out all over 1803 phone calls, getting immediate response by the patient or family in about 85% of cases. The average adherence to treatment during the period was

TABLE II. SUMMARY OF ACTIVITY

					Total
Years	2010	2011	2012	2013	4
patients (mean)	30	29,7	25,5	23,6	28,4
transmissions	536	730	831	357	2097
Adherence %	21,9	24,0	33,7	35,6	28,86%
Spirometry	658	1048	1060	399	2766
Pulse oximetry	183	231	292	104	706
symptoms		322	709	318	1031
phone calls	466	592	745	333	1803
answers			618	285	618
% answers/calls			82,6	85,6	83,7%
inpatients	11	15	54	14	94

28.86%, with increasing trend over time. We carried out, following the transmissions, 94 recalls in hospital which affected 24 patients (11 calls in 2010, 15 in 2011, 54 in 2012 and 14 in the first five months of 2013). Regarding the proceedings run, in 51% of cases the recall was followed by a Day Hospital and 33% by a hospitalization. In 6% of cases only a visit was performed (Fig.1).

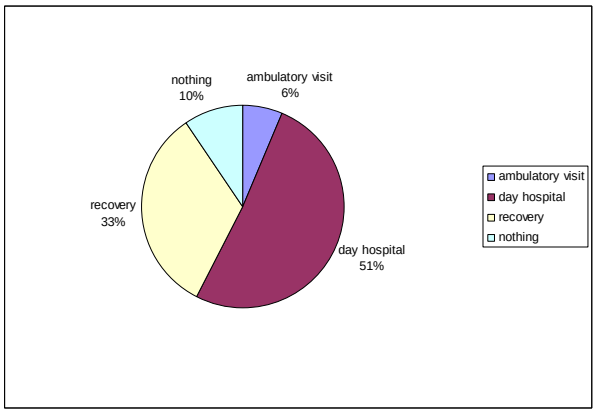

Fig.1. Measures that have followed the recalls.

Regarding the economic aspect, the long-term follow-up with telehomecare resulted in a total calculated savings compared to the traditional method of € 414,985.87 in 39 months corresponding to € 5,320.33 per year per patient recalled (Table 3).

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Obviously, the economic analysis refers to the parameters of remuneration of Italian National Health System, and therefore are only valid in this context.

TABLE III. COST ANALYSIS

Unitary costs	
hospitalisation	€ 4.065,00
Day Hospital	€ 266,00
Ambulatory visit	€ 32,00
Iv home cycle (21days)	€ 2.027,00
Oral home cycle (21 gg)	€ 283,00
SpirotelTM Monthly Loan	€ 210,00
Working day	€ 147,00
Observation period months	39
Patients involved n.	24
Retrievals n.	94
Telemedicine -	
Cost for 94 admissions (inpatient + outpatient therapy)	€ 580.638,93
Telemedicine +	
Cost of the services actually provided (NHS)	€ 235.304,06
Instrumentation rental for 24 patients	€ 187.530,00
Total costs	€ 422.834,06
Income for further utilization of beds	€ 239.835,00
Revenue for recovery of working days	€ 17.346,00
Total savings	€ 257.181,00
Effective cost of Telemedicine+ (cost - savings)	€ 165.653,06
Balance	
Saving (Telemedicine- - Telemedicine+)	€ 414.985,87
Annual saving per patient	€ 5.320,33

IV. DISCUSSION

We observed an annual growth in the number of transmissions despite the decrease of the number of patients followed. This fact shows an increasing use of the system.

The progressive increase of Adherence to treatment means a better overall use of the method. Regarding the frequency of the transmissions, we have recommended to our patients a variable interval depending on the clinical condition, generally 2 times a week at least. In this sense, we expect the optimal adherence to treatment to be 100% for 2 transmissions per week / 5 working days. We got in clinical practice a constant and progressive increase of treatment's adherence to achieve in practice a doubling of the values during the period under review (Table 2). It is also to consider that CF patients are already burdened with a continuous load and considerable therapies, both medical and physiotherapy, and that this result has yet been obtained without requiring a precise timetable for recording. The method we have used in daily practice, described and discussed in a previous study, has remained unchanged. We report the objective fact that from 2011 we have started to call via cell phone always patients after a transmission, even under conditions of clinical stability. It is not possible to evaluate how much this has contributed to the increase in the values of adherence to treatment, at the current stage. The fact remains that this is the only change made in the protocol of follow-up. The possibility of a link between these data is interesting and certainly requires further studies to be defined.

The mobile phone was the medium we used to establish the contact. The percentage of successful calls appears to have improved over time, but the mobile phone, in our opinion, continues to be valuable but not always completely reliable.

From the economic point of view, the presence of an economic advantage for the INHS is confirmed, even if not important. The increase in the calculated savings compared to our previous study indicates in our opinion a better efficiency of follow-up.

Some of our patients in telemedicine have never been recalled. For them it is impossible to carry out an assessment of the cost-effectiveness of telemonitoring that, in this case, has resulted only in costs.

There are currently no universally accepted criteria for inclusion of patients with CF in a telemonitoring program [11]. In Italy, in particular, telemonitoring is not within the Essential Levels of Assistance (LEA) provided by our National Health Service. The viability of telemonitoring still depends, in individual cases, on voluntarily resources made available by the local health authorities.

From the perspective of economic and organizational constraints, it seems necessary to arrive to uniquely define as soon as possible the criteria for inclusion, both in relation to the individual clinical situation both at the lowest adherence to the method that is compatible with a clinical benefit, as well as economic. In our opinion, the advantage in terms of quality of life for these patients remains in any case, resulting from the fact of having at home a tool that allows them to remain in contact with the CF centre more easily, which is certainly important, however, and could also be measured in terms of economy.

V. CONCLUSIONS

The trend of both quantitative and qualitative parameters of our work is positive. The data are encouraging with regard to the possible role of telemedicine in the organization of homecare of chronic diseases. In the current state, however, reliable data on the long-term effectiveness of the use of Telehomecare in CF are lacking.

VI. FUTURE WORKS

Data on the real long-term effectiveness of the use of Telehomecare in CF can only be obtained through a study of controlled type, for which appear the time to be ripe to format.

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Implementing Transnational Telemedicine Solutions

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***Abstract*—The Implementing Transnational Telemedicine Solutions (ITTS) project aimed to implement transnational telemedicine solutions at scale across Europe's Northern Periphery Program area, introducing new telemedicine applications to remote and rural areas in order to improve healthcare delivery for rural communities. ITTS incorporated ten demonstrator projects, which shared knowledge and experience between six project partners and clinical teams in order to simplify the process of subsequent implementation. Across 9 of the 10 demonstrator projects, a total of 25 new services in more than 40 sites across the program area have now been implemented successfully, and are in use with patients. A mixed methods assessment will determine whether the projects become effective and sustainable. This paper documents the process of knowledge exchange and implementation and describes the services now in place. Evaluation results will subsequently be reported and published as a policy-informing guide. ITTS has shown, to date, that transnational knowledge sharing can facilitate the implementation of telemedicine solutions.**

Keywords- telemedicine; eHealth; transnational; implementation

I. INTRODUCTION

Telemedicine and eHealth have been identified as important tools in the delivery of health care in the 21st century. EU eHealth strategy aims to improve citizens' health by making life-saving information available using eHealth tools, to increase healthcare quality and access by making eHealth part of health policy and coordinating EU countries' political, financial and technical strategies, and to make eHealth tools more effective, user-friendly and widely accepted [1]. Each of the countries involved has developed strategy accordingly. The Scottish Government released a National Delivery Plan that sets out the vital contributions of telehealth and telecare to health and care strategies in Scotland until 2015, including enabling services for 300,000 more people and normalising use of the technology into relevant services [2]. In Northern Ireland, the Telemonitoring NI service a scalable, mainstream, end-to-end service which provides a clinical triage service, was launched in 2011, aiming to benefit around 20,000 people over the following six years [3]. The Norwegian Centre for Integrated Care and Telemedicine [4] is the world's largest centre for research and development in telemedicine and e-health and is based in Tromsø. It has provided advisory services, plus research and development of telemedicine solutions since 1993.

Delivering healthcare to remote and rural populations is a significant challenge, requiring innovative strategies to overcome infrastructure deficits, travel difficulties and staffing problems. There is an urgent need to reduce transport costs and carbon footprint, plus a growing acknowledgement that models of long-term care will have to evolve to cope with demographic changes and the economic downturn. Telemedicine may help to provide equity of health service regardless of distance from major centres of care. Yet telemedicine is not in common use; while there have been numerous pilot studies, on completion technology is often withdrawn and the services have not been sustained. The disconnected nature of developments has meant similar problems are often encountered during each new implementation and knowledge is not shared between sites. Implementing Transnational Telemedicine Solutions (ITTS) proposed transnational knowledge exchange about services already proven to work in one country [5], using this knowledge to implement services in new settings.

ITTS was a project partly funded by the EU Northern Periphery Program (NPP), which aimed to implement

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transnational telemedicine solutions in an effective and sustainable manner, normalising them into everyday practice. The plans for the project have been documented [6]. ITTS began in September 2011 and finished in March 2014, and built on previous work which mapped telemedicine services available in remote and rural areas of Northern Europe [7]. Six NPP area countries were actively involved and ten demonstrator telemedicine projects were implemented. The project teams were: Scotland (Lead Partner): Centre for Rural Health, University of Aberdeen; Finland: Oulu Arc Subregion; Ireland: National University of Ireland, Galway; Northern Ireland: Centre for Connected Health & Social Care; Norway: Norwegian Centre for Integrated Care and Telemedicine (NST); and Sweden: County Council of Västerbotten.

The objectives of ITTS were to create sustainable, long-term projects, enabling the uptake of transnational best practice and normalising the use of technology into everyday practice, at scale. ITTS aimed to improve accessibility by situating services in local communities, or in patients' homes, and reducing unnecessary hospital visits and travel for patients and staff. It also aimed to demonstrate cost-effective service delivery and evaluate the return on investment, encouraging the development of eHealth as a key business sector in the region. It was hoped this would encourage further development of telemedicine in remote and rural areas.

The ten demonstrator projects were classified into three themes: videoconferencing consultations; smartphone and internet based mobile self-management; and home-based health services. While most of the technology used in the demonstrator projects is in existence, the implementation occurred in new sites, and in a co-ordinated fashion to promote sustainability.

The major benefit of videoconferencing (VC) is to save travel time and costs, either for the patient who can contact their doctor at a site nearer their home, or for the healthcare staff, who need not travel large distances to visit patients. It also allows the introduction of services to areas that have been previously deemed too remote to allow cost-effective access. Because VC can use readily available, relatively inexpensive technology with which many people and institutions now have experience, it is a simple and economic introduction to telemedicine for clinics [8].

Smartphones are becoming increasingly popular and can provide reminders, symptom or activity tracking facilities, and of course, communication with health services, among many other features, allowing an inexpensive method of interaction with large numbers of patients. Similarly to websites, they can support self-management programs, providing an exchange of information for various health areas and the potential for patients to participate in their health care more pro-actively, thereby reducing the burden on existing services [9][10].

Finally, home-based care is of particular interest to people living in remote and rural areas, especially those who suffer from multiple or complex health and social care needs, and those who are restricted in their ability to travel by illness or mobility issues. Telemedicine can reduce hospital visits and help keep patients in their own communities, bringing care into their homes that they would otherwise not be able to, or have the opportunity to access [11]. The ten demonstrator projects are listed in Figure 1.

Previous work encouraged the idea that countries with experience of specific telemedicine implementations could 'export' their currently existing project to 'importing' countries which had little or no experience of the application [7]. This knowledge allows technology to embed more rapidly, anticipating and overcoming obstacles before they arise. ITTS had access to a wide range of experts within the different partner countries, with a similarly wide range of experience. However, the different countries have varying health systems and infrastructure capabilities, plus different legal situations, and so some 'translation' between countries is needed. An International Telemedicine Advisory Service (ITAS) was created to advise on all elements of the project planning, implementation and analysis. ITAS comprised telemedicine experts from all of the participating countries.

Project 1: VC links for speech therapy services *(Ire, NI, Scot, Swed)*
Project 2: VC links for renal services *(NI, Nor, Scot, Swed)*
Project 3: VC links for emergency psychiatry services *(Nor, Scot)*
Project 4: VC links for remote diabetes services *(NI, Scot)*

Project 5: Smartphones for tracking physical activity *(Ire, Nor, Scot)*
Project 6: Smartphones and internet support for diabetes
Project 7: Smartphones for inflammatory bowel disease *(Ire)*

Project 8: Remote support in medical and social care emergencies *(Fin)*
Project 9: Remote exercise classes for rehabilitation *(Fin, Ire, Scot, Swed)*
Project 10: Home-based service delivery for multimorbidity patients *(Fin, Ire, Swed)*

Figure 1: The ten demonstrator projects with the participating countries

Previous work [6] described the plan and proposed methods of the ITTS project (summarised briefly in section II). Section III presents new results of two years work in the implementation of this plan. Conclusions are drawn in Section IV. Future assessment will demonstrate whether there are travel savings, and whether the services are effective, sustainable and improve access to healthcare in remote and rural communities.

II. METHODS

The ITTS project began in September 2011 with projects identified from previous work [7]. Each participating country identified whether there was any telemedicine activity for the subject areas in their region and scoped the potential for its introduction. Potential sites were assessed for appropriateness and readiness. Each country identified which demonstrator projects they felt able to proceed with. Business cases were created to provide details of the clinical teams, aims, risks and expected impact of the projects, and the financial investments required. The project funding allowed for some purchase of telemedicine equipment for the demonstrator projects in each country. The business cases were reviewed by ITAS, who provided comments on the design and implementation strategies. Their feedback was addressed before any implementation began. Project development workers liaised with the clinical teams, organising all aspects of the implementation from assessing

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requirements to purchasing and installation. Once the technology was installed and staff trained in its use, the services were offered to patients, followed by the start of data collection for the evaluation.

The evaluation aimed to ascertain whether the demonstrator projects worked in each country, the factors associated with successful and unsuccessful implementation and the cost implications. Assessment examined patients' access to services, changes in hospital visits and travel for patients and staff, patient and staff views on their experiences of the services, social and cultural factors affecting implementation and sustainability and cost savings and return on investment from the projects. The methodology for this 'mixed methods' evaluation of the ten demonstrator projects was selected based upon the Model for Assessment of Telemedicine (MAST) [11]. It included the e-Health Implementation Toolkit (e-HIT) [12], to assess readiness and potential barriers to implementation; questionnaires and interviews with clinical staff and patients using the new services; details of health service and travel activity before and after implementation; and a health economics analysis including socio-economic scenarios modelling the impact of expansion of the new services.

III. RESULTS

The majority of the demonstrator projects have now been successfully implemented: ITTS has supported the development of 25 new services at more than 40 sites in the six participating countries. Table 1 provides details of these services.

Project 1: VC links for speech therapy services (Ire, NI, Scot, Swed)

Scotland and Sweden had both previously delivered speech and language therapy (SLT) services using VC systems to link hospitals [5]. VC has the potential to reduce travel costs for patients or therapists; for example, in Scotland therapists can travel for up to a 6-hour return journey to see a patient for an hour-long appointment. Reducing travel time releases time for therapists to see other patients. VC also facilitates the provision of intensive therapy courses requiring shorter but more frequent sessions. Various patients benefit from SLT, and ITTS implemented services with stroke patients in Northern Ireland, head and neck cancer patients in Sweden, and children with speech difficulties in Ireland. VC systems were located in patients' homes in Sweden, or within local community hospitals in remote or island regions such as the Aran Islands in Ireland and the Scottish Highlands.

Project 2: VC links for renal services (NI, Nor, Scot, Swed)

Existing renal VC services were expanded in Norway and Scotland and were exported to Northern Ireland and Sweden. Norway supported patients who are undergoing haemodialysis in their homes in addition to linking central and remote clinics. Scotland expanded their service to offer outpatient review appointments between the main hospital in Inverness and local renal units in Fort William and the Western Isles. Sweden set up links between Umeå hospital and local hospitals in Skellefteå and Lycksele to improve staff support and access to specialist care. Northern Ireland introduced home-based haemodialysis.

Project 3: VC links for emergency psychiatry services (Nor, Scot)

Emergency services cover out of hours assessments of patients in need of acute psychiatric help. VC connections with specialists can help prevent the automatic transfer and admission of patients by providing an assessment of the patient at the initial hospital, wherever that might be located. Norwegian studies have demonstrated that both patients and professionals reported no differences in quality and satisfaction between face to face consultations and VC assessments [14]. Reducing patient travel can help prevent additional distress and allows patients to remain near to the stability of home and carers. Norway had previously implemented 24-hour consultant VC cover from Tromsø and in ITTS expanded their service to include care for adolescent patients in Narvik, Lødingen and Tysfjord, as well as exporting it to Lorn and Islands Hospital, Oban, in Scotland. VC was also being used in multi-disciplinary team reviews to include community teams in ward rounds to help prepare for patient discharge and transfer.

Project 4: VC links for remote diabetes services (NI, Scot)

VC for diabetes services allows local access to specialists without the patients having to travel as far, or as often for several different appointments. Readings from blood glucose meters can be included in the VC link. VC was used in Scotland for patients with diabetes for annual or biannual review appointments, connecting the Inverness-based consultant with patients accompanied by diabetes specialist nurses based at community hospitals in Thurso. ITTS expanded the service to include Fort William and Portree on the Isle of Skye. Existing services in Orkney were extended to include smaller islands, where the VC is also used to connect three sites across the islands with the main centre at Balfour Hospital, with the option of a 3-way link to specialists in Aberdeen. The service was exported to Northern Ireland, connecting Ulster Hospital with Bangor Hospital.

Project 5: Smartphones for tracking physical activity (Ire, Nor, Scot)

The combination of the growing problem of obesity and the increasing popularity of smartphones motivated this project in which the accelerometer sensors in phones were used to monitor physical activity. A survey of pedometer applications (apps) was made and a suitable program chosen: Accupedo by Corusen LLC (Texas, USA). This app runs in the background as users go about their daily tasks and provides graphs detailing daily step count and progress

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TABLE I. SERVICES IMPLEMENTED BY COUNTRY

Project	Finland	Ireland	N. Ireland	Norway	Scotland	Sweden
VC links for speech therapy services	-	VC between the National University of Ireland Galway and the Aran Islands for paediatric patients. Start: August 2013	VC connection to stroke patients' homes in Newry and Mourne, plus a local health centre. Start: November/ December 2013	-	VC network in the northern Highlands is expanding and connecting to specialist services in Aberdeen and London.	Expanding use to head and neck cancer patients, connecting to patients' homes around Västerbotten.
VC links for renal services	-	-	Home haemodialysis support and care reviews. Start: November/ December 2013	Home peritoneal dialysis support via VC. Start: May 2012	VC consultations between Inverness, Fort William and the Western Isles. Start May 2013	VC network between hospitals in Skellefteå, Lycksele and Umeå. Start: November 2012
VC links for emergency psychiatry services	-	-	-	Connects Tromsø to Narvik, Lødingen and Tysfjord for assessment of paediatric/adolescent patients. Start: October 2013	Mobile VC connections between Lorn and Islands Hospital, Oban and on-call psychiatrists. Start: July 2013	Withdrawn
VC links for remote diabetes services	-	-	VC consultation between Ulster Hospital and Bangor Hospital. Start: February 2013	-	Expanding VC network between Inverness, Portree, Fort William and Thurso, plus links between Orkney island hospitals and Aberdeen.	-
Smartphones for tracking physical activity	-	Following a pilot trial, four GP clinics are 'prescribing' the app. Start: April 2013	-	App available at a Healthy Living Centre in Tromso, a public activity service for unemployed people and a Weight Loss Club. Start: May 2013	One Highland GP clinic offering the app. Start: May 2013	
Smartphones for inflamatory bowel disease	-	Consultant at National University of Ireland, Galway offers the app to patients. Start: September 2013	-	-	-	-
Remote support in medical and social care emergencies	Telehealth technology installed in Oulu Arc area nursing home. Start: May 2013	-	-	-	-	-
Remote exercise classes for rehabilitation	Classes delivered to elderly patients' homes in Oulu Arc area. Start: January 2013	Classes delivered in person and to COPD patients' homes in County Clare. Start: January 2013	Withdrawn	-	Classes delivered in person to COPD patients at Wick and Fort William, plus link to remote centres at Golspie and Broadford. Start: August – October 2013	Classes delivered to long-term pain patients' homes in Västerbotten. Start: May 2013

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TABLE I. SERVICES IMPLEMENTED BY COUNTRY (CONTINUED)

Home-based service delivery for patients with multimorbidity	VC support for Oulu Arc area patients with multimorbidity living at home, plus a health website providing test results and a method of communicating with health staff. Start: Oct 2012	Health room within a County Clare GP surgery offers monitoring equipment: BP, pulse oximeter, respiratory/ peak flow, BMI; plus exercise quipment:, health promotion DVD. Start: June 2013	-	-	-	Self-measurement of blood pressure at centres in Malå, Sorsele and Storuman. 'Check-up Bag equipment for nurses visiting patients to measure BP and calculate INR. Start: Nov2012 – May 2013

toward daily goals. The partners in Ireland ran a randomised controlled trial with the app [15] to determine its effectiveness and a suitable protocol for export to the other countries. The app was 'prescribed' by GPs in Ireland and Scotland and used by weight loss groups in Norway.

Project 6: Smartphones and internet support for diabetes

Diabetes is a condition that has massively increased in the past decade and is expected to further grow in the next few years [16]. There are already a large number of websites and smartphone apps to help users with the disease and partly because of this profusion, little is known about which are worthwhile recommending to patients. No new services were implemented within ITTS in this project; instead an international knowledge exchange was organised to tackle this complex subject area. Various stakeholders, including primary and secondary care clinicians, patients, technology developers and other interested parties, contributed to a discussion about diabetes telemedicine. Topics of particular interest included supporting self-management, providing access to integrated information, encouraging lifestyle changes, maintaining patient engagement, remote monitoring and improving access to care. Information and evidence about useful technology, smartphone and internet applications and other resources relevant to diabetes care was collated, and a network of expertise and resources created. A position paper is being written and future projects planned.

Project 7: Smartphones for inflammatory bowel disease (Ire)

A smartphone app was developed and trialled in Scotland in a collaboration between a surgeon at Raigmore Hospital, Inverness, and a technology developer company (Open Brolly, Forres, Scotland) to help monitor inflammatory bowel disease, and through ITTS this was exported to Galway, Ireland. The app allows patients to record and transmit their symptoms to a specialist nurse, with details of their medication use. The nurse views data on a central 'dashboard' which highlights any changes in patients' conditions, allowing the nurse to contact the patient and advise on any management adjustments required. This prompt response should help reassure patients, prevent unnecessary outpatient appointments and reduce admissions.
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Project 8: Remote support in medical and social care emergencies (Fin)

Northern Ireland in particular has considerable experience with telecare systems to support people with health or social care needs and help them to remain independent at home. Finland imported this service for frail elderly people in nursing homes who are given alarms which link to a centre from which help can be sent promptly.

Project 9: Remote exercise classes for rehabilitation (Fin, Ire, Scot, Swed)

VC rehabilitation classes for people with chronic obstructive pulmonary disease (COPD) or other conditions where guided exercise can be useful are particularly advantageous because such patients often experience difficulty travelling and the ability to take the classes at home or at a local hospital is beneficial. Remote patients perform the exercises and benefit from the same social, educational and clinical interactions as those physically present at the clinic. Scotland exported this project to Finland, where it is used with the elderly in their homes; in Ireland, where COPD patients participate in classes from home; and Sweden with patients suffering from long-term pain conditions. In Scotland, the service has been implemented in new sites using a 'hub and spoke' model, with physiotherapists in larger COPD clinics in Wick and Fort William leading classes for those present while also linking to remote community clinics in Golspie and Broadford. It is hoped that more clinics can join the links.

Project 10: Home-based service delivery for patients with multimorbidity (Fin, Ire, Swed)

Based on previous experience of home-based services for patients with complex care requirements, this project took different forms in different countries. In County Clare, Ireland, a self-monitoring station based within a GP clinic where patients can check their blood pressure and weight and use exercise equipment was implemented. In Sweden, clinic-based blood pressure self-monitoring services were implemented in Malå, Sorsele and Storuman, in addition to a second service: a "check-up bag" that nurses used on home visits to evaluate blood pressure and calculate the INR blood clotting measure. In Finland's Oulu Arc Subregion, patients used a web portal to access laboratory results, monitor their health and contact healthcare staff with any questions, plus

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housebound patients with social and health care needs were offered a VC care option.

At the time of writing, only three projects were not yet fully implemented and it was expected that continued effort would result in their implementation at a later date. The implementation of projects at two sites was cancelled due to service and department restructuring or closures. Many challenges were overcome, providing significant learning points, such as working with hospital IT departments to ensure that equipment is correctly installed and determined to be safe and secure, especially in projects where systems were located in patient homes. Other issues included information flow from management to front-line staff, and the effects of staff turnover.

Initial feedback from patients suggested they appreciated the time and travel saving that VC allowed. Those using home-based services said they enjoyed the social interaction the video links offered, as well as the access to services they would otherwise not have been able to use. Complaints mainly referred to connection quality: intermittent problems with the sound or picture on VC, for example.

ITTS collected and analysed data from the demonstrator projects. Results from the evaluation will be reported, and recommendations made aiming to help others interested in starting their own telemedicine services. Planned dissemination of the project results includes presenting the results from the demonstrator projects and cost analysis in peer-reviewed journal articles; attendance at various conference and policy-informing events; a report collecting together all the business cases ("A Case for Telemedicine"); and a guide containing an interactive checklist ("Telemedicine into Everyday Practice") aimed at policymakers and service planners, all of which will be available on the project website [17].

IV. CONCLUSION AND FUTURE WORK

Historically, telemedicine has rarely moved beyond pilot projects. The reasons include infrastructure issues, organisational barriers – both clinical and cultural – economic considerations and governance and security concerns. ITTS implemented telemedicine services across northern Europe, using transnational knowledge exchange to facilitate implementation, and encouraging success and sustainability. Patients are now using these services as a direct result of the project. ITTS has implemented 25 new telemedicine services across the six countries, offering benefits to patients and staff and showcasing what the available technology can achieve. Assessment will provide evidence about effectiveness and sustainability, but the achievement of implementing this number of telemedicine applications, from the initial planning stage [6], to the stage where they are operational should not be underestimated. This is the stage where many pilots fail, without attention to organisational issues.

The challenges of implementing solutions that are sustainable, transnational, and that bring telemedicine into everyday practice are considerable, but this project has demonstrated the impact of strategic investment. The goal of the project was to implement transnational telemedicine solutions, in an effective and sustainable manner. Effectiveness and sustainability are as yet to be measured, but ITTS has created expert networks which will hopefully continue beyond the project timeline. This contribution will form a foundation for further work as those services which are successful mature and expand, and new applications are developed. ITTS has provided a demonstration of what can be achieved with transnational collaboration and efforts to ensure knowledge and experience is shared in practical ways.

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Videoconferencing Solution: Through Innovation Extension to Attain and Support Pre-Alzheimer Patients in Their Daily Activities

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***Abstract*—The main objective of this paper is to come up with a practical Voice over Internet Protocol approach to support elderly patients affected by Alzheimer disease in their daily activities. This is done by enhancing and integrating the existing Open Source features. The whole development embroiled the integration possibilities of voice, video and instant messaging services in order to improve communication processes between local Session Initial Protocol servers and clients. Part of the proposed work is the remote control tab feature that will be used to control the robot machine and the Living lab framework for knowledge creation and sharing. The preliminary tests and developments have verified that Ekiga softphone running on robot machine can accept and direct orders from Asterisks server in a form of audio and video. The information was gathered through literature review and this was conducted through the use of case studies, white papers, peer-reviewed conference papers and journals.**

Keywords-Ekiga; Videoconferencing; Leaving-Lab.

I. INTRODUCTION

There is a correlation behaviour that elderly patients leave hospital early because of medical expenses, yet they still need additional care at their home to recover from their illness. It is believed that treating a patient at home is less expensive than treating them in hospitals. In this context, there is a need for technological tools that will support and help to deploy the integrated care for elderly and chronic patients. According to Mapundu and Simonnet [6], there are widely acknowledged imperatives for helping elderly patients living at home (semi)-independently for as long as possible. The purpose of this study is to integrate and test the existing Voice over Internet Protocol (VoIP) tools that will help elderly people to have trust relationships and be able to communicate with their family members and caregivers as to avoid loneliness.

One of the tools that will be implemented is a good video quality of Videoconferencing Service that will act as a main communication channel between elderly people, robot companion, family caregivers and medical professionals. An Asterisk Private Branch eXchange (PBX) server solution is implemented and tested in order to manage the communication process between local SIP servers and SIP clients. Session Initial Protocol (SIP) is an application layer signalling protocol for creating, modifying and terminating multimedia session among one or more participants [10]. This paper addresses Videoconferencing Service through identifying different problems concerning the existing VoIP tools and new developments that will be needed, with the aim to accomplish the following objectives : Analyse codec's functions whether problems are resulting from Session Initial Protocol (SIP) servers (Asterisk/ Kamailio), Testing and making new working version of Ekiga that support H261, H263, H263+ and H264, this involves integration and cross-compilation processes for Microsoft Operating Systems and Open Source Operating Systems, Integration possibilities of an Internet Protocol (IP) cameras that will support Real Time Streaming Protocol (RTSP) whereby voice orders can be assigned or dialled to an IP camera and access it using RTSP services and A proposed remote control for the robot machine that will use a 3rd channel support for sending and receiving orders (audio, video, S-command channels data streams).

The intention was to come up with a practical VoIP approach which could be accomplished by integrating and testing the various open source tools that are available as a way forward to achieve the above objectives. The review of Research Questions gave us an understanding of the Research problem as a whole and it gave us a clear reflection of knowing which VoIP tools should be implemented and integrated. The follow section summarises some research questions that we looked at. Does the problem of codec's compression and decompression result from softphone clients, and which tools must be implemented to address such?, Can the IP cameras accept orders from PBX SIP server in a form of audio and videos

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using RTSP services, if possible are there any delays?, For auto-negotiation of 3rd channel support, would it be possible for robot operator to utilize send and receive data streams either in a form video, sound, s-command from private, public SIP servers to the robot machine?, Does Real-time Transport Protocol (RTP) transmits and encapsulates the voice data streams between endpoints for more than one call in a single packet, if possible does it reduce the IP overheard without increases the latency? Do Session Initial Protocol (SIP) servers have a commitment to support latest version of Ekiga clients with modification for Graphical User Interface (GUI) implementation, if so are there more specific technical requirements that might be needed?

The content of this work follows a simplified strategic planning process; it was conducted as a literature review which starts by introducing the current state of VoIP technologies and its interconnection based on articles and continues to research the existing literature in order to discover theories behind interconnections. The experimental scientific research approach with VoIP supporting tools were conducted and applied in order to address the main objectives. This paper starts by describing the overall research background, VoIP establishment, and research results and concludes with some future work.

II. RESEARCH BACKGROUND AND RELATED WORK

European Scientists have found three new major genetic links to pre-Alzheimer, affecting up to 20% of people with brain-wasting disease. It was the most significant such discovery in 15 years. Alzheimer disease affects more than 26 million people globally and it has no cure with any good treatment. The need for effective remedies is pressing on, with the number of cases estimated to go beyond 100 million by 2050 [5]. According to Matos [11], many European projects have focused on support of technologies for elderly are on process, CompanionAble is one of the projects. In response to the problem, Roceries and Simonnet [8], developed, operate and maintain a Telemedicine platform that offers communication and assistance services to patients, especially for elderly people. This platform has two main components, namely a Central Server and Local Equipment for Domestic Internet Gateway (DIG). Both these components use a secured Internet Protocol Network over Internet (Virtual Private Networks). This platform is easy to deploy because all functions and related virtualized servers can be held on one physical server [8]. Actually, the platform is operating at Ecole Supèrieure d'lngènieurs en Èlectronique et Electrotechnique Paris University but the aim is to install it in any hospital that might need it. Each patient at home will have a DIG that provides Internet service and records operational data such as agendas and monitor data to mitigate temporary internet access failure. This platform must integrate the communication process for elderly patients to keep a strong social link with their families or caregivers and doctors, thus a good videoconferencing services will be implemented to provide a high quality of video output with low latency and jitter.

Integration and evaluation have to be conducted in regard to embedded Voice over Internet Protocol solutions by testing the latest developed codec's and diagnose the performance because there are challenges about the quality of the video output. We need to develop and conduct preliminary tests to assess the possibilities of adding a new that will be used to pilot or direct robot machine and it can be replaced by the joystick in future. The choice of the softphone and codec's is critical because the Asterisk does not allow codec translation. This needs that all clients must be compatible. An interface is hard to design due to dialling and meeting process; therefore, it will be difficult to use the same communication channel [8]. The integration procedures on how to stream data (video, audio) in IP Cameras using RTSP services and this communication channel will need to support specific delays.

Healthcare systems face a number of challenges in the coming years. These relate to confidentiality of data, changing demographics and economics of European society [3]. Effective delivery of healthcare in the future is therefore likely to depend on a combination of technological solutions [7]. Human needs are complex and are not necessarily easily met through simple technological fixes, provision of human services (social and health) involving many ingredients, thus some can be supported by the types of functionality provided by technology. According to European Commission Final ICT and Ageing Report [12], there is a risk that too much 'technology' push might result in inappropriate application and negative outcomes, to detriment of those immediately concerned as well as to the longer-term prospects for the community or market. On the other hand, application of technology in human service, delaying or blocking innovations that can provide truly positive benefits for elderly people and their care-givers. However, the potential offered by technology also extends to other domains; this comprises the general social inclusion of elderly people in everyday social life and support for ageing in the context of employment or daily activities [12]. Currently the European Commission is dedicated in providing the health-care support for elderly patients to all European citizens. Not as an advantage, but as a fundamental right for many citizens who lacks the most basic services [11]. To accomplish this goal, both private and public health care sectors have identified Videoconferencing as a strategic tool to improve the health-care delivery and instructive services to elderly patients with the aim of reducing medical care costs. As seen in Figure 1, this is research work collaboration and the collaboration involves academics, private and public sectors with the aim to support elderly patients in their daily activities. Number 8 in Figure 1 is ESIEE Paris University, where the proposed Videoconference solution is being developed.

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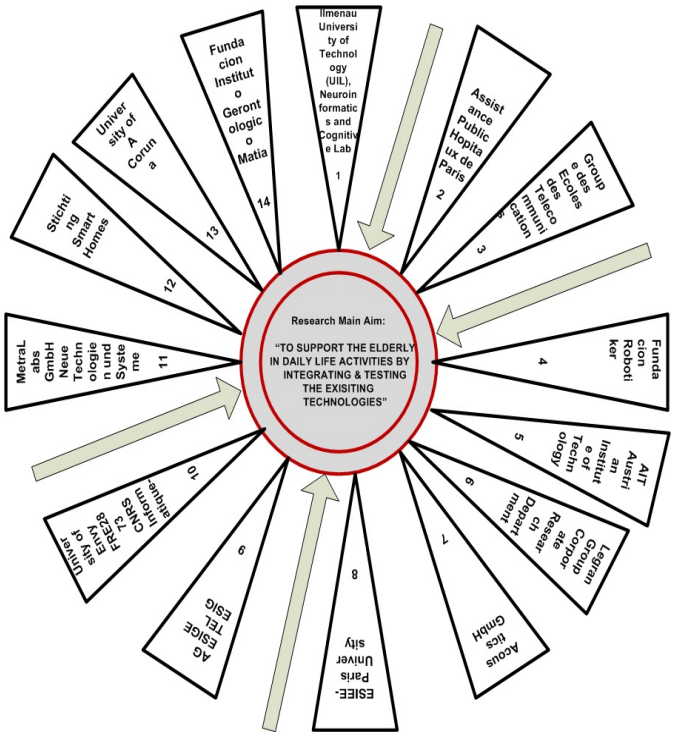

Figure 1. Research Collaboration.

III. ESTABLISHING VOIP CONNECTION WITH SIP CLIENTS AND SIP SERVERS

According to Bley [1], the process of compiling and running Ekiga with its sources normally require tools like a working of C/ C++ compiling environment and it depends on three dependencies that are developed together for compilation process for instance: Ptlib, Opal and Ekiga. According to Boundy [2], the above dependencies are attributes that can be defined in the package stanza files. They allows for defining hardware and software prerequisites and restrictions to be evaluated when executing the compiled, remove, and undo commands on the package [2]. If users want to compile and install a new working version of Ekiga, they should make sure that they don't have dependencies or packages that are already installed in their machines. We managed to follow the relevant steps to compile the Ekiga client on Debian and Ubuntu machine (Open Source OS) and this involve downloading, save the Ekiga packages and compiled them. For Windows Operating Systems (OS), currently it is not possible to build Ekiga for Windows on Windows machine. The current process to build Ekiga for Windows is to generate a 32 bit program (win32) through cross-building on a GNU/Linux system.

The powerful SIP client-server application supports user mobility with two operating modes: Proxy and Redirect. Figure 2 shows a SIP Proxy mode, whereby SIP clients send requests to the proxy server and the proxy server either handles the requests or forwards them to other SIP servers. On the other side of users in VoIP network, the signalling invitations look as if they are coming from the proxy SIP server [3].

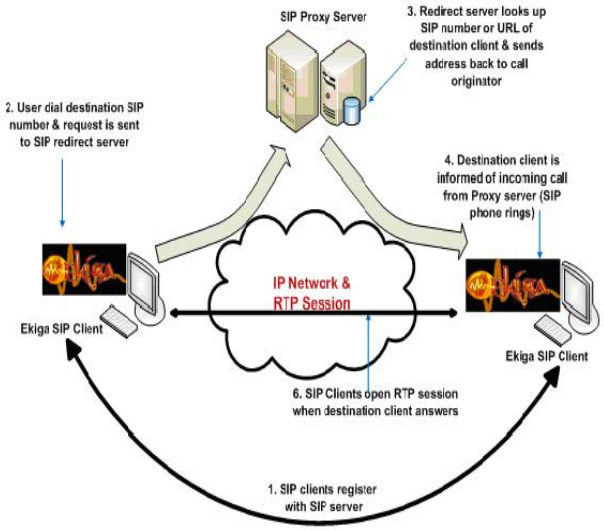

Figure 2. SIP Architecture [7].

The minimal set of modules needed for various Asterisk and Kamailio functions was determined based on the minimum requirements and using the requirements makes it possible to develop tests for the target functionalities of these two PBX systems. We managed to configure and install certain services and modules for SIP servers (Asterisk and Kamailio). Primary, we took consideration of minimal requirements thus two sets of requirements, each describing a set of abilities necessary for the project. The first set of requirements pertains to support for SIP based phone calls; we call a minimal Asterisk, Kamailio PBX system meeting the voice call and video requirements. The next set of minimum requirements includes some additional support for voice mail PBX system. Before selecting the packages required, firstly install a database that will store users and generally MySQL is recommended for testing procedures. After the file system has been formatted, the user will be presented with the option to select packages or to use default packages and we followed all the relevant installation steps to configure and setup both Destar Asterisk 1.6.1.0 and Kamailio 3.0.0. Primary for database creation, inside the file /etc/kamailio/kamctlrc the following lines were inserted in the following format:

```
SIP_DOMAIN=soult.esiee.fr
DBENGINE=MYSQL
DBRWUSER=openser
DBRWPW="openserrw"
DBROUSER=openserro
DBROPW=openserro
DBROOTUSER="root"
```

One of the objectives was to activate the RTSP services for an IP camera (SIP client) and Asterisk PBX (SIP server), whereby a call in a form of video and audio (orders) can be dialled and accepted to it and this will provide a means for

choosing delivery channels such as UDP, TCP, RTP mechanisms and etcetera. The AXIS 207W was chosen as an IP camera for this Videoconferencing platform and for installation purposes, we connected the AXIS207W IP camera according to the installation guide then configured the IP address for AXIS 207W camera (the default IP address for this camera was 192.168.0.90 and the SIP client machine was set to 192.168.0.1) and again we configured the Password for AXIS207 camera (when accessing this camera for the first time, the "Configure Root Password" dialog will appear, then we entered a password and re-enter it to confirm. The default user name was 'root', thus it cannot be changed and the password for AXIS 207W camera was set to '1E492'. After the process of compiling and making a working 3.2.6 version of Ekiga, the next step was to modify the Graphical User Interface (GUI) of Ekiga and all the GUI test modification were undertaken in Ubuntu Jaunty 9.0.4, the same machine that Ekiga softphone was compiled. Preliminary tests were conducted by creating and adding two Ekiga tabs, namely, First Tab and robot Control Tab using C, C++ and by editing XML codes with text editor.

IV. RSEARCH OUTCOMES

A. *SIP Clients Running on Windows and Open Source Platform*

The processing of compiling and making a new working version of Ekiga running on Linux and Windows platform is part of our research objectives. The Ekiga softphone was selected as a SIP client for this project, because it's an Open Source application that allows easy modification, unlike other softphones it supports many audio and video codec's selection and is supported both in Open Source & Windows platform [4]. A number of tests were performed for both platforms, and, as seen in Figure 3 and Figure 4, are Ekiga SIP clients that were created.

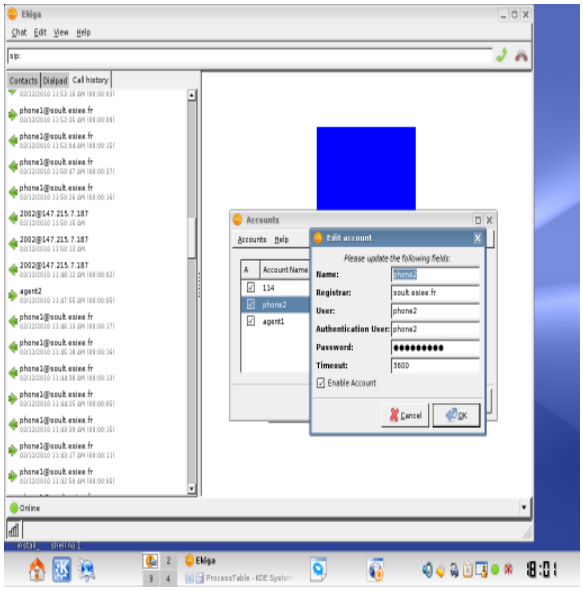

Figure 3. Registering Ekiga client to soult.esiee.fr SIP domain.

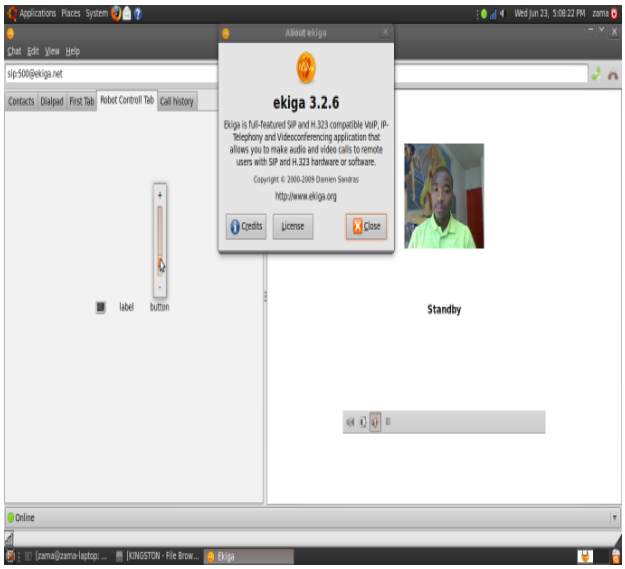

Figure 4. Ekiga SIP client with modified tabs.

Mapundu and Simonnet [6], used Glade interface designer to create the proposed remote control prototype as seen in Figure 5. The intension was to test the possibilities of modifying the GUI of Ekiga with the aim of adding the proposed Remote Control to direct the robot machine and in future it can be replaced by the joystick.

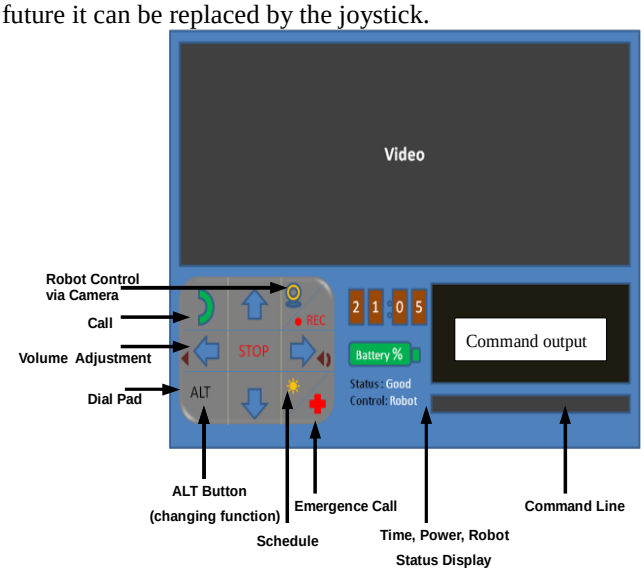

Figure 5. Proposed remote control prototype [6].

After successfully integrating the RTSP services for an IP camera, then the image captured by the camera was displayed as seen on Figure 6, this is an image that was captured by AXIS207W (selected IP camera) at ESIEE Paris test lab environment. Practically you can display the live view page on separate window by issuing the following command: FFplay (in the web link) and you should be on Linux terminal.

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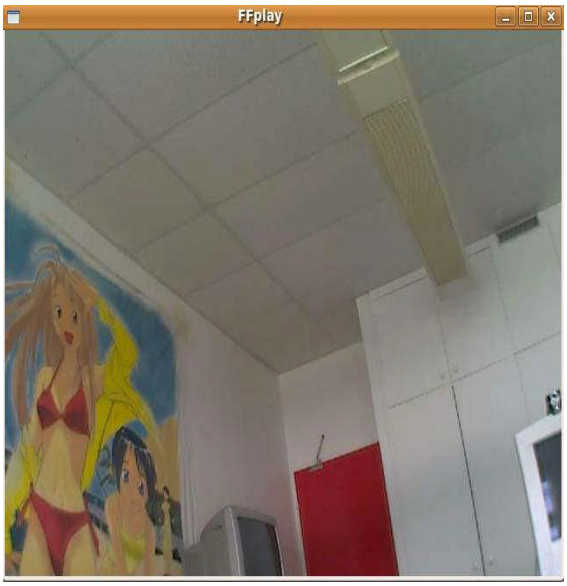

Figure 6. Proposed remote control prototype.

As seen in Figure 7, is DeStar/Asterisk and, in Figure 8, is Kamailio SIP domain, Mapundu and Simonnet [6], managed to configure and install both SIP servers. Before starting Ekiga clients, they need to have a SIP registrar server for communication connectivity of which in this scenario we configured: soult.esiee.fr acting as a Registrar Server and it is possible to issue SIP calls.

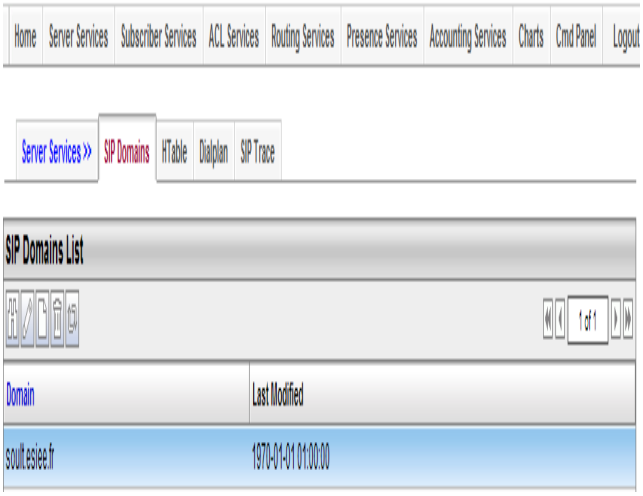

Figure 7. Soult.esiee.fr SIP domain..

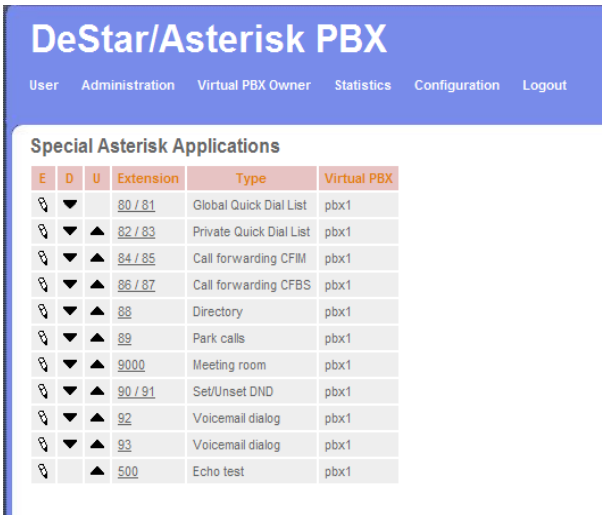

Figure 8. Soult.esiee.fr SIP domain..

After successfully installing the SIP servers, as seen in Table 1, summaries both Kamailio and Asterisk PBX comparison findings.

TABLE I. DESTAR/ASTERISK SIP SERVER VS KAMAILIO SIP SERVER

Function/Specification Support	**Asterisk SIP Server** Supported Status (Yes or No)	**Kamailio SIP Server** Supported Status (Yes or No)
Modelling and Integration	Yes	Yes
SIP support	Yes	Yes
PSTN function	Yes	Yes
Voicemail	Yes	Not Yet
IVR (interactive Voice Response)	Yes	Not Yet
Database Support	Yes	Yes
IP authentication and security	Yes	Yes
Presence Message	Not Yet	Yes
Text Message	Yes	Yes
Interface Management	Yes, AGI	Yes, MI
NAT Support	Yes	Yes
Packet Route	Not yet, some challenges when working with multi-domains	Yes, more used for load balancing and multi-domain support
Multi-domain	Not yet	Yes

V. FUTURE WORK

According to Conklin et al. [13], the development of assisted living and Tele-Health applications requires domain oriented interdisciplinary research as a result there will be a prerequisite for a Living Lab. A Living Lab is an innovative approach to deal with community driven in real life improvement context and it is motivated by knowledge creation, sharing, collaboration and experimenting in open real environments [9]. This approach offers its client group with an opportunity to expand much deeper perceptive of how various mechanisms in their useful locations function and interconnect. According to Jacobus and Zaaiman [9] define living labs as “The Living Lab is a system and

environment for building a future economy in which real-life user centric innovation will be the normal co-creation technique for new products, services and community infrastructure". The impression at the starting point of a Living Lab is to turn clients from being considered as merely subjects to whom new products or services are simple proposed into dynamic players contributing to the co-creation and experimentation of emerging ideas, breakthrough scenarios and innovative concepts [13]. Part of our recommendation in devising a plan of action for Europe, is to pursue the development of Tele-health Living Lab Framework. As seen in Figure 9, this is a Community Living Lab Factory Framework that is developed by [9] and it can be utilised for resource sharing as well as creative and innovation thinking.

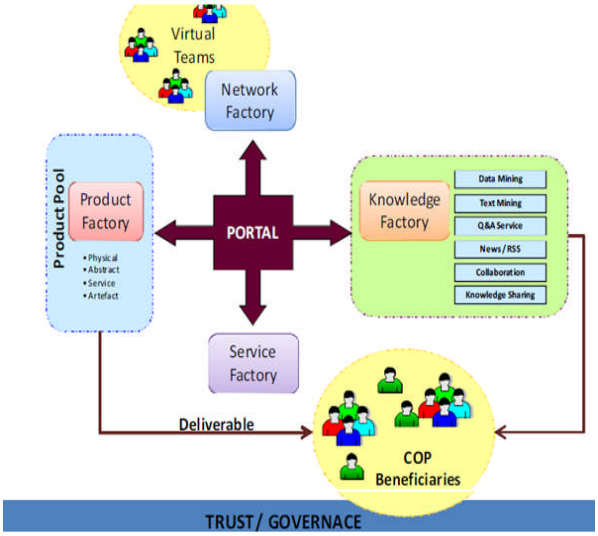

Figure 9. Community Living Lab Framework [9].

In addition to future work in devising action plan for European Countries is to come up with Knowledge Brokers (KBs). The implementation of Knowledge Brokers will promote mutual understanding that gives Researchers, Decision makers and Caregivers a better understanding of each other's environments and this will help to spread the awareness together with adoption of innovations [13]. It should be noted however that the trade off between audio, video quality and throughput performance of this Videoconferencing tool is still ongoing issues.

VI. CONCLUSION

Integrate and test the existing VoIP tools that will help elderly people to have trust relationships with their family or caregivers and one of the tools that was proposed is the implementation of Videoconferencing service (VoIP Tool) that will act as a main communication channel between elderly people, robot Companion, family caregivers and medical professionals. Both assessments from SIP client and SIP server side has been conducted successful but there are still some limitations in regard to some communication services, hence there are some developments with latest versions of Ekiga soft phones and Asterisk PBX systems that are currently examined by VoIP engineers. All this work should be done through The Living Lab approach umbrella; this is an approach that will provide its user group (researchers, community, students, industry, academics and etcetera) with an opportunity to develop much deeper understanding of how various components in their functional environment operate and interrelate [3].

ACKNOWLEDGMENT

Some research leading to these results has received funding from European Community's seventh Framework Programme (FP7/2007-2013, under grant agreement nº216487), French National Research Association through QuaVADis Project.

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Ontology- and Model-Based Quality Indicators Designing Framework

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***Abstract*—Though quality indicators play an important role in assessment of medical service quality of hospitals, there still exists no universal framework to collect or select adequate quality indicators for certain assessment of medical service quality. This paper provides a set of models called "Medical Service Assessment Models (MSAM)" that help collect adequate quality indicators to assess medical service quality from the patients' viewpoint. To this end, we focus on a set of semantic patterns of medical service quality assessment and develop an ontology called "Medical Service Assessment Ontology (MSAO)", which is a vocabulary to construct MSAM based on the patterns. The framework consisting of MSAM and MSAO plays a role in guidelines for collecting adequate quality indicators to assess medial service quality from the patients' viewpoint, and helps explain the basis for the collection of quality indicators.**

Keywords-quality indicator; medical service assessment; ontology

I. INTRODUCTION

Quality indicators play an important role in assessment of medical service quality of hospitals. Recently, medical assessment organizations such as the Agency for Healthcare Research and Quality (AHRQ) [1], the National Institutes of Health (NIH) [11] and the Organisation for Economic Co-operation and Development (OECD) [12] have provided a lot of quality indicators to hospitals and toolkits to calculate values of their indicators based on data in medical databases in hospitals. Moreover, they have compared the values above on the international scale. Such comparisons will expand in the future.

However, there still exists no universal framework to collect or select adequate quality indicators for certain assessment of medical service quality, and hence, each medical assessment organization provides a series of quality indicators in its own and it is not easy to fairly compare medical service qualities based on quality indicators.

This paper provides a set of models that help collect adequate quality indicators to assess medical service quality from the patients' viewpoint. The models are called "Medical Service Assessment Models (MSAMs)". To this end, we focus on a set of semantic patterns of medical service quality assessment and develop an ontology that is a vocabulary to construct MSAM based on the patterns. The patterns and ontology are called "Medical Service Assessment Description Patterns (MSADPs)" and "Medical Service Assessment Ontology (MSAO)", respectively. MSAMs are constructed with instances of concepts and properties in MSAO. MSAO is developed by an ontology developing tool "Semantic Editor" [5].

The framework consisting of MSAO and MSAMs plays a role in a guideline for collecting adequate quality indicators to assess medial service quality from the patients' viewpoint, and helps explain the basis for the collection of quality indicators.

The remainder of this paper is organized as follows. Section 2 explains MSADP. Section 3 introduces MSAO based on MSADPs, and Section 4 introduces MSAMs based on MSAO. Section 5 explains how to design quality indicators based on MSAMs. Sections 6 and 7 explain related works and the conclusion.

II. MEDICAL SERVICE ASSESSMENT DESCRIPTION PATTERNS

Medical Service Assessment Description Patterns (*MSADPs*) are semantic patterns of medical service quality assessment, which are obtained from organizing assessors' thinking how to assess medical services of medical staff in hospitals.

MSADPs consist of the following patterns.

1. What types of medical staff and instruments are there in the hospital?
2. What types of patients have been accepted by the hospital?
3. What treatments have been executed to the patients?
4. What results have the patients obtained after the treatments?
5. In the 4th phase above, how do the results differ from estimates?

MSADPs can be considered to be semantic or description patterns of Donabedian's assessment of medical service

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quality based on the aspects of "constructions, processes and outcomes" of medical services [4] plus acceptance situations of patients. One can also consider that MSADPs are organized from the patients' viewpoints. Therefore, the viewpoint of medical service quality assessments based on MSADPs might be limited more than Donabedian's viewpoint. However, by limiting the scope of the assessment, the way to design quality indicators based on MSADPs can be more systematic than Donabedian's method.

III. MEDICAL SERVICE ASSESSMENT ONTOLOGY

The purpose of this paper is to provide a set of models to design adequate quality indicators for assessment of medical service quality according to MSADPs. To this end, we introduce *Medical Service Assessment Ontology* (*MSAO*), which is a vocabulary to construct the models.

A. Patients

In MSAO, a patient denotes a type of people who share common problems, and problems are mainly classified into problems to be solved by medical services and others called background problems (Fig. 1). The former denotes mainly diseases, while the latter is classified according to age, pregnancy or congenital disorders.

In Fig. 1, yellow (highly-colored) rotundate rectangles describe concepts, while pink (softly-colored) rotundate rectangles with dotted lines describe attributes of concepts. For example, a concept "patient" has two attributes "background" and "target disease", and "background" has the range "background problem", which is a subclass of "problem", where the range of an attribute denotes the set of values of the attribute.

B. Patients' Values and Purposes

A value denotes what a patient wants in solving his/her problems (diseases). A value consists of 8 types of value components in Fig. 2 on the next page. A purpose is regarded as a value plus criteria to attain its value components (Fig. 2).

C. Medical Services

A medical service denotes what is executed to a patient to solve his/her problem(s). Medical services are mainly classified into events and activities (Fig. 3 on the next page). An event is a set of one or multiple activities or smaller events, while an activity is what a medical staff directly executes on the spot. For example, a surgery is regarded as a medical service, while laparotomy is an activity by an operating surgeon in a surgery.

A service in Fig. 3 has four attributes: "target purpose", "approach", "tool", and "then" that indicates the next service of the service. A process of a medical service is a path consisting of events or activities to attain the medical service.

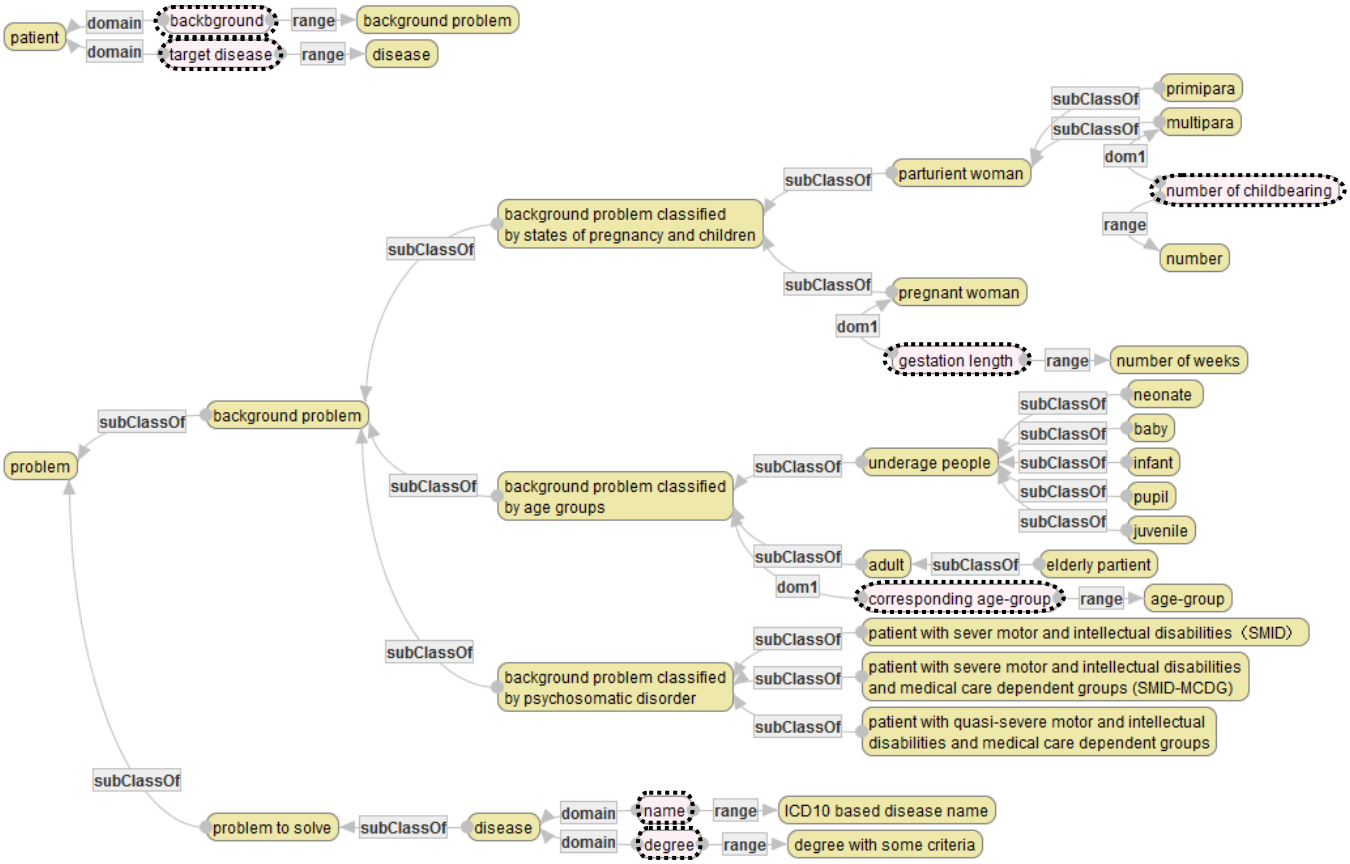

Figure 1. Patients and their problems (Partial)

One can develop process models of medical services by combining instances of medical service concept (cf. Fig. 8 on the last page).

D. Medical staff, instruments and facilities

Medical service providers consist of medical staff, instruments and facilities (Fig. 4).

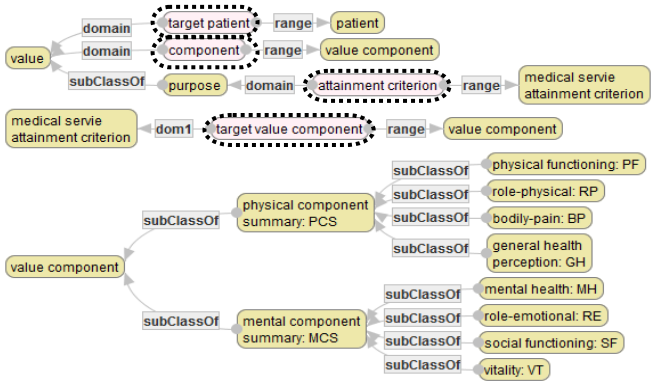

Figure 2. Values and purposes (Partial).

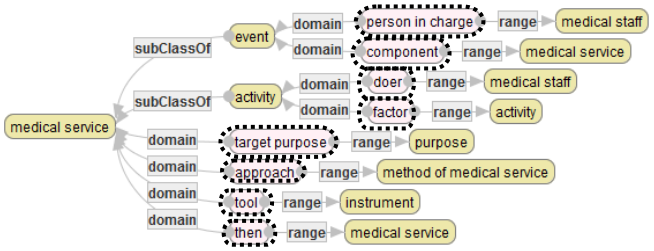

Figure 3. Medical services.

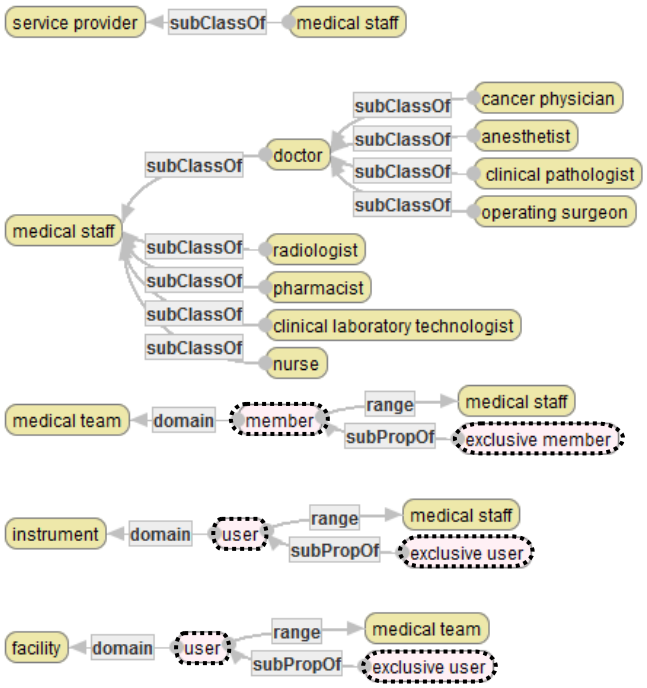

Figure 4. Medical service providers (Partial).

Medical staff are doers or people in charge of a medical service. For example, doctors, anesthetists, radiologists and nurses are typical medical staff. On the other hand, instruments and facilities are hospitals' resources used by medical staff in medical services. In this paper, a medicine is regarded to be one of those instruments. For example, MRI is an instrument, while an operation room is a facility.

E. Patient outcome

A patient outcome denotes a state of a patient that might change through an activity (Fig. 5 on the next page). Patient outcomes are classified into (i) completion, (ii) completion with potential risk, (iii) failure, and (iv) emergency, according to degrees of activity attainments, risks that patients might have through the activity and costs that patients pay for the activity attainments. “Completion” denotes a patient outcome that is obtained by a complete activity with no problem. “Completion with potential risk” denotes a patient outcome from which the next activity is feasible but which has some potential risk(s) that might be actualized in the future. “Failure” denotes that the doer could not complete the activity. Finally, "emergency" denotes that the patient falls into critical situations such as the patient's death by the activity. An accident denotes a negative outcome that a patient conclusively has. Possible outcome (or possible accident) is a pair of a patient outcome (or accident, respectively) and its possibility.

“Completion with potential risk”, “failure” and “emergency” have attributes “risk outcome” and ”risk accident” whose ranges are possible outcome and possible accident respectively, which means that, if these types of patient outcomes occur, then (negative) patient outcomes or accidents might occur in the future. Moreover, “failure” and “emergency” have an attribute “result” with range “fatal accident”, which denotes a serious accident that might halt the medical service including the activity.

IV. MEDICAL SERVICE ASSESSMENT MODELS

In this section, we explain *Medical Service Assessment Models* (*MSAMs*). MSAMs show situations related to medical services from the viewpoints of the five patterns of MSADPs, and they are constructed with instances of concepts in MSAO. Thus, we will explain MSAMs according to the five patterns above.

Prior to constructing MSAMs, one has to set a main service such as "an open abdominal surgery of stomach cancer" that he/she will assess eventually.

The main service above is called a conclusive service. The conclusive service is set by using concepts of patients in MSAO, as follows.

1. Set problems of patients to make clear a conclusive medical service for stomach cancer patients.
2. Set a type and/or stage of target cancer in order to make clear the problem to solve by the medical service.
3. Set background problems of target patients. (As an example, we here consider all patients of stomach cancers with stage II.)

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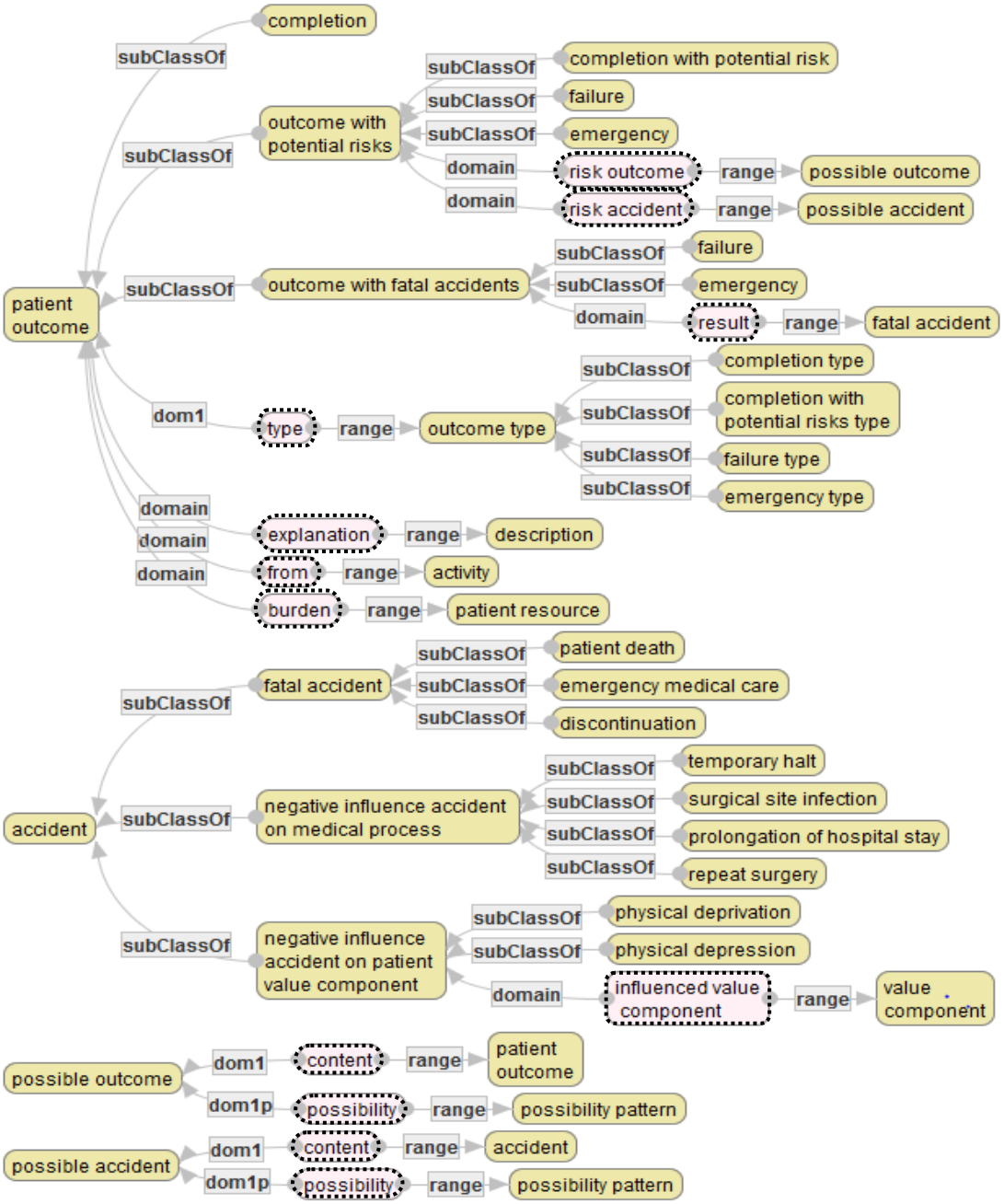

Figure 5. Outcomes of patients (Partial).

4. Set values and purposes for the patients according to the 8 types of value components in Fig. 2. Then, one can also set attainment criteria of patients' satisfaction about the values.

5. Finally, set a conclusive medical service as well as an approach of the conclusive medical service.

As an example of a conclusive medical service, we here consider an open abdominal surgery of stomach cancer. In the following subsections, we construct MSAMs based on the conclusive medical service above.

A. *Medical Service Provider Model*

A *Medical Service Provider Model* (*MSPM*) is a model that shows provisions for a given conclusive medical service. The model is employed to design quality indicators in the first phase of MSADPs.

MSPM consists of medical staff, instruments, facilities and dependency relationships between them. Here, a "dependency relationship" means a relationship between a medical service or a thing related to a medical service such as an instrument or a facility and what plays an exclusive role for the service or the thing. The dependency relationship

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is a transitive relationship. Therefore, for example, the medical staff "operating surgeon" is an exclusive medical staff of an event "open abdominal surgery of stomach cancer". Fig. 6 defines the dependency relationship by the properties "exclusive ...".

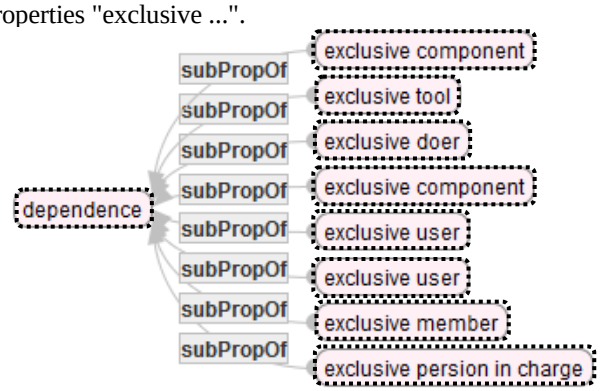

Figure 6. Dependency relationships.

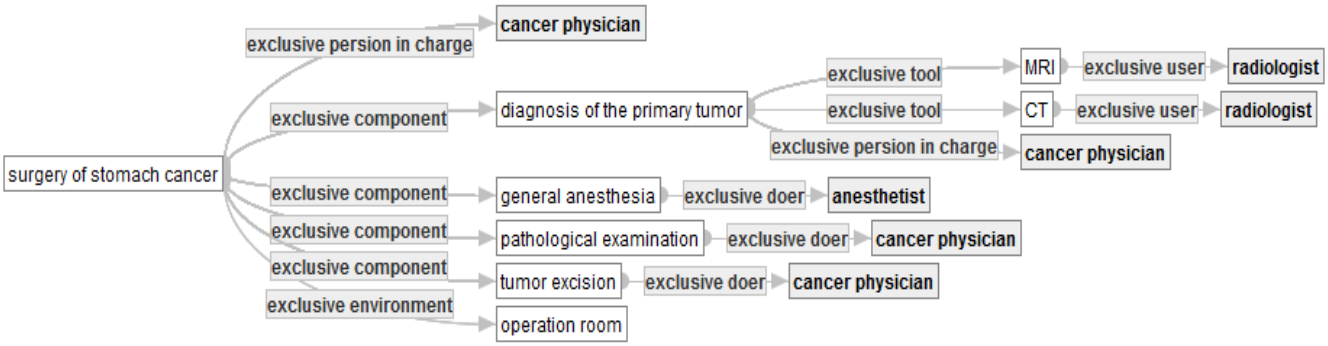

Figure 7. MSPM for open abdominal surgery of stomach cancer (Partial).

Fig. 7 shows an example of MSPM that indicates exclusive or significant medical services, instruments, facilities and medical staff for open abdominal surgery of stomach cancer. Since each instance in Fig. 7 is connected by dependency relationship labelled by "exclusive ...". All instances in Fig. 7 are exclusive or significant for the conclusive medical service.

For example, the small event "diagnosis of the primary tumor" is an exclusive component event of the surgery above, "MRI" and "CT" are exclusive instruments for the diagnosis and "radiologist" is an significant staff who can exclusively use the instruments. Therefore, the small event, instruments and staff above are all exclusive for the surgery.

B. Patient Model

A *Patient Model* (*PM*) is an instance of a patient's concept of MSAO. Thus, the content is what we already have explained in Section 3.1. Here we give an example of a PM "patients of stomach cancers". Moreover, as examples of patients' purposes we give (1) life extension, (2) recovery of life function, (3) recovery of physical function and (4) alleviation of physical and mental pain caused by diseases.

C. Medical Service Process Model

From a given conclusive medical service such as "open abdominal surgery of stomach cancer", some concrete approach and constraints of the medical service can be decided. According to such an approach and/or constraints, one can construct a process model of the medical service, which is called a *Medical Service Process Model* (*MSPrM*). The example of an MSPrM is partially shown in Fig. 8 on the last page.

Fig. 8 shows a process from “diagnosis of primary tumor” to “surgery performance”. Each small event or activity that constitutes the conclusive medical service is assigned to a person in charge or a doer. For example, the small event in Fig. 8 "performance of surgery" consists of eight activities and the person in charge of the small event is a "doctor", while the activity "general anesthesia" in "performance of surgery" is assigned to a doer, an "anesthesist". Moreover, some small events and activities are assigned to instruments and/or facilities.

D. Patient Outcome Model

A *Patient Outcome Model* (*POM*) shows the status of a patient that chances by activities and/or events according to the process of the conclusive medical service. A POM is expressed as a list that consists of possible statuses of a patient through the last small medical service that constitutes the conclusive medical service. A status of a patient through a small medical service that constitutes the conclusive medical service is determined based on the completion degree of the service, potential risks and costs caused by the service.

A POM is constructed through the following steps.

1. Given an MSPM, PM, and MSPrM, sort out patient outcomes by considering the completion degrees, potential risks and costs of the small services that constitutes the MSPrM under the assumption that all services above are executed acceptably. The patient outcomes above are desirable ones.
2. Pick up small events or activities that are not easy to complete with no potential risk and no high cost. Thus, add the undesirable outcomes that are caused by the failure of such small events and/or activities.

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In the case of open abdominal surgery of stomach cancer, one may obtain undesirable patient outcomes including the following outcomes:

i. Tumor excision with a certain level of bleeding,
ii. Tumor excision with surgical site infection,
iii. Tumor excision with light damage to abdominal organs,
iv. Excessive tumor excision,
v. Deficient tumor excision and
vi. Failure of tumor excision by severe damage to abdominal organs or blood vessel.

V. DESIGN OF QUALITY INDICATORS BASED ON MSAMS

In this section, we explain the way to design quality indicators based on given MSAMs that are obtained in the previous section. As well as the previous section, we consider "open abdominal surgery of stomach cancer" as a conclusive medical service. Thus, we will explain how to design quality indicators to assess the quality of the conclusive medical service above in the following subsections.

A. Design of QIs based on MSPM

By virtue of the MSPM that is obtained in Section 4.1, one can clarify significant medical staff, instruments and facilities of the given conclusive medical service. Thus, quality indicators can be defined to be what indicate the status of the resources above.

For example, it is valuable for assessment of the conclusive medical service quality to calculate quality indicators that indicate acceptance situations of medical staff "radiologist", "cancer physician" and "anesthetist", instruments "MRI" and "CT" and a facility "operation room", which are shown as exclusive resources in the MSPM (Fig. 7).

B. Design of QIs based on PM

By virtue of the PM obtained in Section 4.2, target patients of the given conclusive medical service can be figured out. In the case of "stomach cancer patients", quality indicators can be defined to be what indicate acceptance number of patients who are characterized by instances in the PM above.

C. Design of QIs based on MSPrM and POM

By virtue of the POM that is obtained in Section 4.4, one can clarify remarkable patient outcomes, especially, undesirable ones (i, …, vi in Section 4.4). Thus, it is valuable to define quality indicators that indicate frequency of the undesirable patient outcomes above.

For example, the number of surgeries that need a certain amount of blood transfusion or time-lengths reflects the frequency of the undesirable outcomes i and iii. On the other hand, the number of surgeries that need certain lengths of hospital stays reflects the frequency of the outcome that force patients to bear the burden such as the outcomes iii and iv. The rate of SSI is directly related to the outcome ii. Finally, the rate of hospital readmissions and re-surgeries reflect the frequency of the outcomes v and vi.

Finally, we explain how to design quality indicators that correspond to the third step in MSADPs by using MSPrM and POM in Sections 4.3 and 4.4. Through the two models above, one can associate remarkable undesirable outcomes i, ...,vi and small events and/or activities in the MSPrM. Thus, quality indicators that indicate level of skill of such services are important ones of the third pattern of MSADPs.

For example, degree of conformance of scales of tumors in diagnoses before surgeries to scales of tumors that surgery doctors actually excised is related to frequency of the outcomes iv and v in Section 4.4. Thus, the degree of the conformance above may be an important indicator of surgery doctors' skills.

Moreover, the executing rate of additional activities or small events that prevent the outcomes i,...,vi are also important quality indicators of the third pattern of MSADPs

D. Comparison of QID-FW and TDD-FW

The designing framework of quality indicators explained in the previous sections, which we call QI-designing-FW or QID-FW, can be regarded as an analogy of a test-driven development framework (TDD-FW) of information systems. The following table shows correspondence relationships of components of QIDFW and TDD-FW.

TABLE I. COMPARISON OF QID-FW AND TDD-FW

	QID-FW	TDD-FW
1	Medical staff	System users
2	Patients	Data
3	Medical instruments and facilities	Information systems
4	Medical services	Accumulation of data through information systems
5	Medical service provider models	Use case diagrams
6	Patient models	Data models
7	Medical service process models	Business process models
8	Patient outcome models	Models obtained by integration of use case scenarios
9	The model constituting a patient outcome models	Use case scenarios
10	Quality indicators	Tests

The 1st to 3rd items in Table 1 are components that exist initially in working places, while the 5th to 9th items are models or specifications. From the viewpoint of medical informatics, medical services can be regarded as creation and/or modification of patients' data. Thus, the 1st to 3rd components of QID-FW can be regarded as the same components of TDD-FW in Table 1. Therefore, medical service provider models in QID-FW correspond to use case diagrams in TDD-FW, which show relationships between

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users and information systems. Moreover, patient models can be considered to be data models (more properly, master data models), while medical service process models can be considered to be business process models that shows workflows with information systems. Though there do not exist well-known models in TDD-FW that directly correspond to patient outcome models, components of a POM, which show outcomes of activities in a medical service, can be represented by use case scenarios.

On the other hand, a test in the TDD-FW plays the role of a criterion of an information system or a service with the system. So, quality indicators can be regarded as tests in the TDD-FW.

In TDD-FW, developers create efficient tests (or test cases) systematically based on requirement specifications that consists of the 5th to 9th models of TDD-FW in Table 1. Thus, the methodology in QID-FW to design quality indicators, which is based on the idea of tests (test cases) designing in TDD-FW, can be considered to be at least partially reasonable and systematical way to design a set of quality indicators.

VI. Related Work

The paper [4] is one of the representative researches on what quality of medical service is and how to measure medical service quality. Moreover, one can take representative researchers such as Collopy [2], Copnell [3], Mainz [8, 9] and Mainz et al. [10] for development and improvement of quality indicators. These results play significant roles in researches how to express medical service quality as numerical values. This paper introduces a framework based on MSAO and MSAM to effectively employ the methods that the previous researchers have developed in order to obtain ideal standard of medical service quality.

On the other hand, one can take the papers [6] and [7] for instances of development frameworks of ontology for medical information systems. By combining these frameworks and MSAO, one can establish a framework to define ideal quality indicators and to calculate the values of the quality indicators based on data in medical information systems.

VII. Conclusion and Future Work

In order to design adequate quality indicators for assessment of medial service quality from the patients' viewpoint, and to explain the basis for the design of quality indicators above, this paper provides the following products:

1. A set of semantic patterns of medical service quality assessment, which is called "Medical Service Assessment Description Patterns (MSADPs)".

2. A set of models called "Medical Service Assessment Models (MSAMs)" that help collect adequate quality indicators to assess medical service quality from the patients' viewpoint.

3. An ontology called "Medical Service Assessment Ontology (MSAO)", which is a vocabulary to construct MSAM based on MSADPs.

Moreover, we also briefly explain the way to design quality indicators based on the framework consisting of the three products above (see Section 5).

On the other hand, the method of our framework to construct patient outcome models is still highly dependent on individual skills, and it has not yet been sufficiently systematic. Thus, our next subject will be to develop a more systematic method to construct patient outcome models.

Moreover, it is necessary to make our designing framework easier for users including medical staff to use. To this end, we will be required to develop a tool that assists users to make medical service assessment models, and to evaluate the acceptability of the framework among medical staff.

Acknowledgment

This work was supported by a JSPS KAKENHI Grant Number 24500167.

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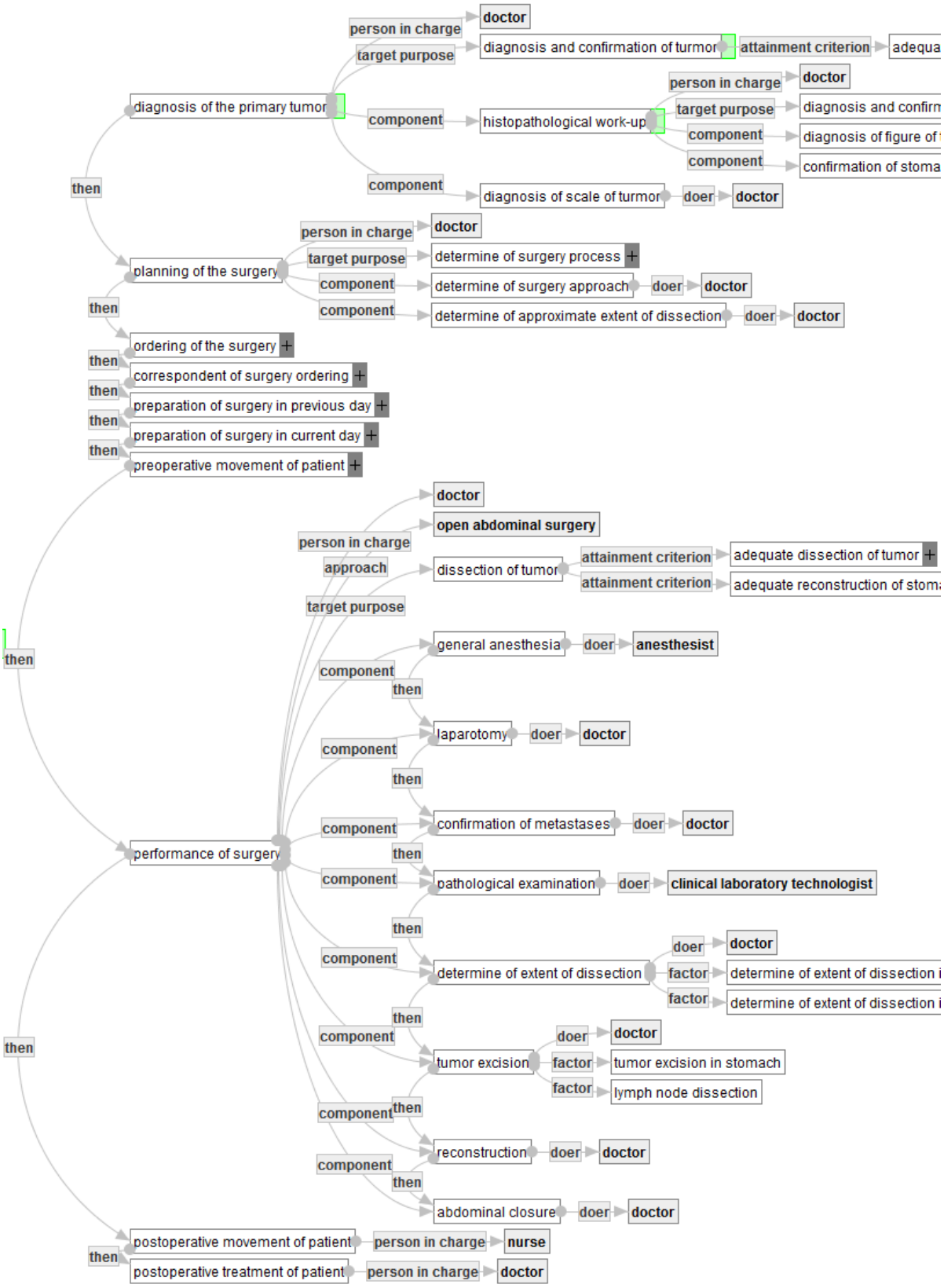

Figure 8. MSPrM of open abdominal surgery of stomach cancer (Partial).

Towards Patient-Centered Telemedicine

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***Abstract*— Patient-centered care is an emerging healthcare model that is changing how people think about health and about the patients themselves. It emphasizes the coordination and integration of care, and the use of appropriate information, communication, and education technologies in connecting patients, caregivers, physicians, nurses, and others into a healthcare team where the health system supports and encourages cooperation among team members. However, in spite of the widespread adoption of telemedicine, existing telemedicine applications do not support patient centered-care. In this paper, we present our designed cloud based telemedicine system that supports patient-centered care. It exploits Personal Health Records (PHRs) in sharing patient's clinical documents, and it manages medical consultation requests by exploiting a Consultation ontology. The system and the PHRs may be located anywhere in the Internet, and its consulting organizations may include any healthcare provider having the ability for consultation.**

Keywords - telemedicine; patient-centered care; personal health records; CCD standard, cloud computing; ontologies; eHealth ecosystem

I. INTRODUCTION

Telemedicine is the use of telecommunication and information technologies in order to provide clinical health care at a distance [1]. It aims to eliminate distance barriers and can improve access to medical services that would often not be consistently available in distant rural communities [2]. In particular, telemedicine is viewed as a cost-effective alternative to the more traditional face-to-face way of providing medical care [3].

At the same time, the introduction of new emerging healthcare trends, such as patient-centered care [4], pharmaceutical care [5], and personal health records (PHRs) [6], are changing how people think about health and about the patients themselves. In addition, many studies have demonstrated that the provision of these healthcare models can increase compliance with treatment regimens, satisfaction with the health care provider and medical facility, and improve the ultimate health outcome for the individual [7].

It is also true that patients who do not understand their treatment instructions, disease management, or prescription requirements are more likely to mishandle their health, be hospitalized more frequently, and have much higher medical costs than their more involved counterparts [8].

Unfortunately, none of the categories of telemedicine support these emerging healthcare trends: *Store-and-forward telemedicine* involves acquiring medical data and then transmitting this data to the system that is accessible to patient's physician. *Interactive services* provide real-time interactions between patient and physician. It includes phone conversations, online communication and home visits. *Remote monitoring* enables medical professionals to monitor a patient remotely using various technological devices.

Patient-centered care emphasizes the coordination and integration of care, and the use of appropriate information, communication, and education technologies in connecting patients, caregivers, physicians, nurses, and other into a healthcare team where health the system supports and encourages cooperation among team members [9]. It is based on the assumption that physicians, patients and their families have the ability to obtain and understand health information and services, and make appropriate health decisions.

Pharmaceutical care emphasizes the movement of pharmacy practice away from its original role on drug supply towards a more inclusive focus on patient care **[**10**].** It emphasizes the responsible provision of drug therapy for the purpose of achieving definite outcomes that improve patient's quality of life [11].

A PHR is a record of a consumer that includes data gathered from different sources such as from health care providers, pharmacies, insures and the consumer [12]. It includes information about medications, allergies, vaccinations, illnesses, laboratory and other test results, and surgeries and other procedures [13]. PHRs are owned by the patients and they can only be accessed by the patient and those that are authorized by the patient.

In our vision PHRs can significantly contribute to the introduction of patient-centered care. Further in telemedicine they do not only improve the quality of care but also significantly increase the efficiency of consulting physicians. PHRs also allow individuals to access and coordinate their lifelong health information and make appropriate parts of it available to those that are authorized by the individual [14].

Further, cloud computing [15] provides an ideal technical infrastructure for a variety of e-health services including PHRs. As anyone with a suitable Internet connection and a standard browser can access an application in a cloud, sharing patient's clinical documentation among the healthcare team is straightforward to those that are authorized by the patient.

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In this paper, we describe our work on designing a cloud-based telemedicine system that captures PHRs and manages consultation requests by a software module called *Consultation server*. It changes the traditional telemedicine paradigm: its main goal is not only to provide a cost-effective alternative to the more traditional face-to-face way of providing medical care but rather to provide a data infrastructure for information sharing among patient's healthcare team.

Further, our designed telemedicine infrastructure allows location independence in the sense that the consultation manager, called *Consultation Server*, and the PHRs may be located anywhere in the Internet, and its stakeholders may include any healthcare provider having the ability for consultation. Further, a patient can be cared in any place having an Internet connection. Thus, such a global architecture also changes the traditional telemedicine ecosystems which only aim to provide clinical health care at a distance.

In the design of the Consultation Server we have followed the idea of knowledge oriented organizations [16]. Its key idea is to revolve all applications around a shared ontology. The main gain of such architecture is that the applications that manage the consultation related data can interoperate by accessing the shared ontology, which in our architecture is called *Consultation ontology*. It is specified in OWL (Web Ontology Language) [17], and so the applications can query the ontology by SPARQL [18]. As OWL ontologies and its instances are presented in RDF (Resource Description Framework) [19], the ontology is updated by inserting RDF-statements in the ontology.

In our introduced terminology the participants of the Consultation Server that agree to work together for practicing telemedicine is called as a *telemedicine affinity domain*. Examples of possible telemedicine affinity domains include nationwide and regional affinity domains, regional federations made up of several local hospitals, healthcare providers, and insurance provider supported communities.

A useful feature of a telemedicine affinity domain is that it is global: its components can locate anywhere in the Internet, and it can be exploited by patients and consulting physicians as far as they have an Internet connection.

The notion of telemedicine affinity domain has similarities with the *clinical affinity domain* of the IHE XDS [20], which studies the problem of patient's scattered clinical documentation. Its key idea is that patient's clinical documents are dynamically retrieved from a clinical affinity domain by exploiting relevant registries. This model assumes that patients' clinical documentation follow them as they move from one clinical affinity domain to another. Another difference between IHE XDS and PHRs is that in the former patient's clinical documentation is managed by healthcare authorities while in the latter they are managed by a patient.

The rest of the paper is organized as follows. First, in Section 2, we give a motivating scenario of our ideas in practice. Then, in Section 3, we consider the structure of CCD documents and show how they can be used for exchanging clinical information as well as structuring PHRs. In Section 4, we present the architecture of the Consultation Server and the Consultation Ontology in a graphical way. We also give a variety of useful queries that the ontology enables. In Section 5, we do not consider the Consultation Server from technology point but rather as ecosystems having many interconnected parts. Finally, Section 6 concludes the paper by analyzing potential risks that may jeopardize the deployment of our designed telemedicine system. We also shortly consider our future work on integrating the Consultation Server with other e-health tools used by the physicians.

II. MOTIVATING SCENARIO

Assume that a patient, named Nancy Taylor, has an online Web-based free personal PHR, where her health data and information related to the care given to her is stored. She can access her PHR from any place having an Internet connection.

One day Nancy discovered a rash on her waist, and so she decided to visit the nearest general practitioner having a contract with a telemedicine affinity domain. The practitioner examines Nancy's rush but the practitioner does not know what kind of treatment or medication should be prescribed for Nancy, and so the practitioner decides to request medical consultation by his Web browser.

To carry out the consultation the practitioner first takes a photo from Nancy's waist. Then the practitioner fills the request document by describing the symptoms of the rash and attaches the photo to the document. The document also provides a hierarchical classification (i.e., a taxonomy) of diseases. The practitioner marks the node "skin disease". In addition, authorized by Nancy the practitioner adds a link to Nancy's PHR and authorization for its use (including required access rights). Finally, the practitioner clicks the submit button, and so the document is delivered to the Consultation Server, which maintains a queue of the pending requests.

Each request includes a set of metadata items such as disease(s), source of request, language and possible priority of the request. The function of the metadata items is to enable automatic matching of the requests and the consulting physicians. So the Consultation Server shows for a consulting physician only the requests that match with his or her profile. Therefore, each consulting physician of the affinity domain also has a profile, which has values for the metadata items and is stored in the Consultation Server.

Assume that a physician, named John Smith, is a specialist in a hospital of a telemedicine affinity domain. In addition his profile matches with the request concerning Nancy, and so the request is in the consultation request queue shown for him.

After a few minutes John Smith picks up the consultation request document and examines the symptoms described in the document as well as the attached photo. Immediately he recognizes Nancy's rash as shingles (herpes zoster), which can be treated by a medicinal product named Aciclovir. Then he checks from Nancy's PHR whether Nancy has some allergies that would prevent the use of the drug or whether she has some ongoing medical treatment that could cause mutual negative effects. As there are no such findings the

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physician updates Nancy's PHR by the prescribed medication and by the diagnosis he made. Finally John constructs and signs the prescription electronically, which is then electronically delivered to the general practitioner visited by Nancy.

III. USING CCD STANDARD IN PHRS

A. PHRs vs. EHRs

In medical consultation, as well as in any medical treatment, a complete and accurate summary of the health and medical history of the patient is of prime importance. A problem here is that as a patient may have lived in various places and a patient may have many healthcare providers, including primary care physician, specialist, therapists and other medical practitioners, patient's health documentation may be distributed over several healthcare providers.

PHRs provide a simple way for solving the problem of patients' scattered clinical documentation [21]. They differ from EHRs (Electronic Health Record) [22] in that they are owned by the patients and they can only be accessed by the patient and those that are authorized by the patient while EHRs assume that the health records are designed only for use by health care providers and are owned by medical authorities.

Managing fragmented healthcare documentation by EHRs has been successful only in a very few industrialized countries, such as in Singapore and Denmark [23]. Instead successful results from the use of PHRs are reported from many countries and communities. Therefore we have also concluded that the use of PHRs instead of national EHR's in managing patients' health documentation is a more appropriate solution in the context of telemedicine.

B. Web-Based PHRs

PHRs can be classified according to the platform by which they are delivered. In web-based PHRs health information is stored at a remote server, and so the information can be shared with health care providers. They also have the capacity to import data from other information sources such as a hospital laboratory and physician office. However, importing data to PHRs from other sources requires the standardization of PHR-formats.

Various standardization efforts on PHRs have been done. In particular, the use of the Continuity of Care Record (CCR standard) of ASTM [24] and HL7's [24] Continuity of Care Document (CCD standard) [25] has been proposed. From technology point of view CCR and CCD-standards represent two different XML schemas designed to store patient clinical summaries [23]. However, both schemas are identical in their scope in the sense that they contain the same data elements.

Web-based PHRs are core components in our proposed ecosystem. However, it does not assume that all patients have a PHR, but it encourages patient to acquire a PHR. Using a PHR does not require patients to own any personal devices for internet connection nor any efforts for managing it. Rather it requires patient to authorize healthcare personnel to maintain and access their PHR.

Acquiring a PHR is a tempting opportunity as there are many freely available web-based PHRs available, and moving personal data between standard-based PHR is supported by the vendors. For example, as the support of the Google Health was retired on January 2012 Microsoft has developed a transfer process for the user of the Google Health for moving their health records into Health Vault. Similar to Dossia and World Medical Card, it is a web-based system to store, maintain and share health and fitness information. They support a number of exchange formats including industry standards such as the CCR and CCD standards.

C. CCD Standard

We have given preference to CCD standard (an XML schema) as it is nowadays increasingly used for specifying the structure of exchanged clinical documents as well as specifying the structure of the PHR. This feature simplifies the update of the PHR as well as the generation of the clinical documents that will be stored in the PHR.

Further, we have assumed that XML based CCD and CCR standards are the most appropriate standards as they are commonly used within PHRs. Their schemas contain the same data elements, and thereby transformation between these formats can be easily done.

The CCD standard is a constraint on the HL7 CDA standard. The CCD standard has been endorsed by HIMMS (Healthcare Information and Management Systems Society Though) [26] and HITSP (Healthcare Information Technology Standards Panel) [27] as the recommend standard for exchange of electronic exchange of components of health information.

Although the original purpose of the CCD documents was to deliver clinical summaries between healthcare organizations, nowadays the XML schema of the CDD documents is increasingly used for specifying the structure of the PHRs. The same schema can be used in message as all its parts are optional, and it is practical to mix and match the sections that are needed.

D. The Structure of a CCD document

Each CCD document have one primary purpose (which is the reason for the generation of the document), such as patient admission, transfer, or inpatient discharge. Further, each CCD document, as well all HL7 CDA documents, is comprised of the Header and the Body.

A CCD document that includes a header and the Medications section from the Body is presented in Fig. 1. The content of the document is derived from the scenario presented in Section 2, i.e., the document would be inserted in Nancy Taylor's PHR, which is based on the CCD-standard.

In a PHR the CCD documents are usually organized into hierarchical structures that simplify the search of documents, e.g., grouping together the documents by episode, clinical specialty or time period. Yet each clinical document is stored as a stand-alone artifact, meaning that each document is complete and whole in itself.

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```
<CCDfile>
  <DocumentID>DOC_123</DocumentID>
  <Patient>
    <PatientID>AB-12345></PatientID>
    <PatientName>Nancy Taylor></PatientName>
  </Patient>
  <Medications>
    <Medication>
      <MedicationID>Medication.567</MedicationID>
      <DateTime>
        <ExactDateTime>2012-03-01TO12:00</ExactDateTime>
      </DateTime>
      <Source>
        <Actor>
          <ActorID>Pharmacy of  Health</ActorID>
          <ActorRole>Pharmacy</ActorRole>
        </Actor>
      </Source>
      <Description>
        <Text>Two tablets twice a day</Text>
      </Description>
      <Product>
        <ProductName>Aciclovir </ProductName>
        <BrandName>Zovirax</BrandName>
      </Product>
      <Strenght>
        <Value>400</Value>
        <Unit>milligram</Unit>
      </Strenght>
      <Quantity>
        <Value>40</Value>
        <Unit>Tabs</Unit>
      </Quantity>
    </Medication>
  </Medications>
</CCDfile>
```

Figure 1. A simplified example of a CCD document.

IV. CONSULTATION SERVER

A. The Architecture of the Comsultation Server

In designing the internal architecture of the Consultation Server we have followed the idea of knowledge oriented organizations [16, 28], where the key idea is to revolve all applications around a shared ontology. As illustrated in Fig. 2, in our solution all the applications of the Consultation Server are revolved around the Consultation Ontology.

The users access the Consultation Ontology through the Consultation Portal, which provides connections to the relevant cloud applications. The applications are based on the use cases of the various user groups. For example, Submit Consultation Request and Pick-up a Consultation Request are two typical applications developed for physicians. These applications interoperate through accessing the same data items included in the Consultation Ontology.

Note that although the Consultation ontology is specified in QWL and queried by SPARQL (i.e., by a RDF-based query language), it is stored for the efficiency reasons in a relational database [29].

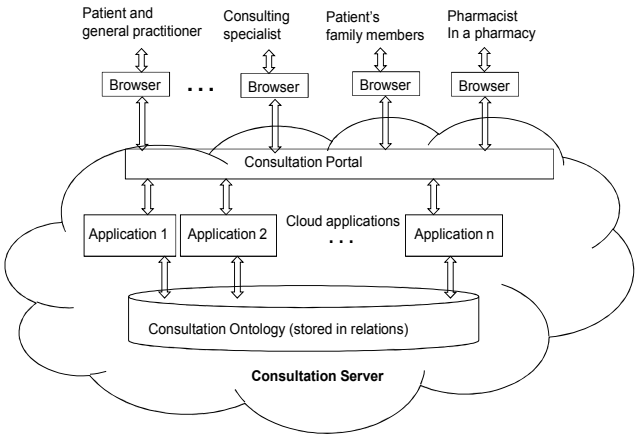

Figure 2. The components of the cloud-based Consultation Server.

B. The Structure of the Consultation Ontology

A portion of the Consultation ontology is graphically presented in Fig. 3. In this graphical representation ellipses represent classes and rectangles represent data type and object properties. *Object properties* relate objects to other objects while *data type properties* relate objects to datatype values. Classes, data type properties and object properties are modelling primitives in OWL [17].

Note that in Fig. 3 we have presented only a few of objects' datatype properties. For example, in the figure we have omitted most of the datatype properties from the classes Physician and Organization. Instead all the datatype properties of the class Consultation request are presented in the figure. The class Speciality and its datatype property Class represent a taxonomy. That is, except for the root node there is a link from each class instance to its parent.

The idea behind this taxonomy is that the symptoms and the specialities of the physicians are specified by the same vocabulary. This feature simplifies the matching of consultation requests and physicians' specialities.

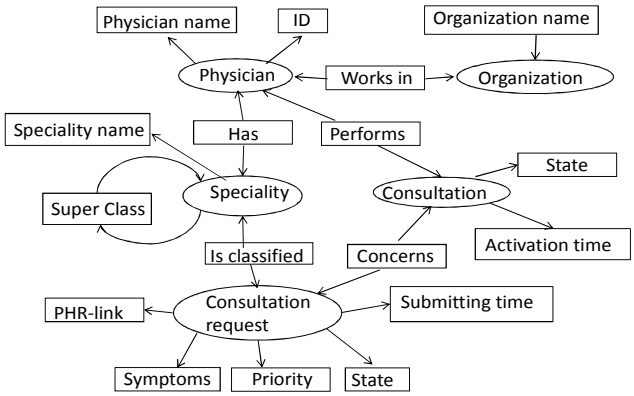

Figure 3. Graphical presentation of a portion of the Consultation Ontology.

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The Consultation Ontology enables a variety of useful queries for physicians such as the followings:

- Is there any pending consultation request having classification "Skin diseases".
- Is there (in the affinity domain) any physicians having speciality in diabetes.
- Is there any consultation request matching with my speciality.
- Is there any pending consultation request that is submitted by a physician of the University Hospital.
- Is there any consultation request that has been pending over ten minutes.
- Give me the names and specialties of the consulting physicians that work in a specific affinity domain.

Note that the Consultation Server can support more than one telemedicine affinity domain. Further, as most OWL ontologies, such as the Consultation Ontology, are usually stored in relational database systems, it is also possible to use the triggering mechanism of the SQL [30] in automating the management of the consultation requests. For example, a request can be automatically allocated to a physician having required speciality and having no ongoing consultation.

C. Cloud Computing and SaaS

Cloud computing is an appropriate choice for telemedicine consultation management as it allows organizations to use applications without installation. Moreover, in most cases cloud-based solutions reduces the cost of acquiring, delivering, and maintaining computing power [15]. However, in our vision the main goal behind cloud computing is to achieve synergy through controlled sharing of data.

In particular the Saas (Software as a Service) model of cloud computing is appropriate for the Consultation Server. It is a software delivery model in which applications are hosted by service provider and made available to customers over the Internet. It provides access to software and its functions remotely as a Web-based service.

Further, there are various architectural ways for implementing the SaaS model. For example, in the case where the Consultation Server serves more than one telemedicine affinity domain we could use the following software architectures:

1. Each telemedicine affinity domain has a customized version of the Competence Server that runs as its own instance.
2. Many telemedicine affinity domains use separate instances of the same application code.
3. A single program instance serves all telemedicine affinity domains.

In our designed version the Consultation Server supports only one clinical affinity domain as so only one version and one instance is required.

V. TELEMEDICINE ECOSYSTEM

To succeed e-health systems should not be considered just as a technical infrastructure but rather as ecosystems having many interconnected parts [31].

So far we have considered the technical infrastructure and the services of our designed telemedicine oriented cloud-based ecosystem. The other key parts of the ecosystem are governance regulations, financing and stakeholders. For now, we shortly consider what kind of new alternatives the introduction of cloud-based solutions gives for these parts of the ecosystem.

A. Governance Regulations

E-health application that maintains patients' health documentation must adhere to national legislated policies and regulations, which concerns privacy and security issues. One problem is that in many countries that are just beginning to investigate on e-health application do not yet have enough mature legislation with respect to e-health. Thereby national governments have an important role in promoting the development of appropriate legislation concerning e-health.

In our developed telemedicine ecosystem patient's health documentation is not stored in the national archives but rather on PHR system, where the patient's health documentation is owned by the patient and only used by the physicians, patient's family members and healthcare personnel authored by the patient. As a result, patients' health documentation is not under the control of national healthcare authorities, and thus is not so tightly dependent on whether there is advanced legislation for e-health.

B. Financing Cloud-Based E-Health Ecosystems

In designing an e-health ecosystem it is important to ensure that appropriate funding is in place for its implementation and operation. Financing can come from a variety of sources, such as government or public-private partnerships.

Financing PHRs is not an actual problem as there are many freely available web-based PHRs available. Further there are many freely available PHRs for specific communities, e.g., for employees of specific organization, customers of a specific insurance company or for the customers of a specific healthcare provider.

C. Stakeholders of Global Ecosystem

In designing the implementation of an e-health ecosystem, it is of prime importance to involve in preparation all the key stakeholders, such as governments, public and private healthcare providers, patients, as well as patient advocacy groups [31].

As our proposed ecosystem is not nationwide but rather "internet-wide", the system itself as well as its stakeholders may span over many countries. For example, governments and healthcare providers from a variety of countries may be involved in the ecosystem, and each stakeholder has different objectives and motivations for participating in the ecosystem.

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VI. CONCLUSION AND FUTURE WORK

The goal of our work has been to show that cloud-based global telemedicine ecosystems that support patient centered care can be implemented from technology point of view. Yet there are many problems that may jeopardize the success of such ecosystems. In particular, the introduction of new technology requires training: the incorrect usage of a new telemedicine technology, due to lack of proper training, may ruin the whole ecosystem. In addition, a consequence of introducing a new telemedicine practice is that it significantly changes the daily duties of the healthcare personnel, and the role of patient and patient's family members. Therefore one challenging aspect is also the changing the mind-set of the involved healthcare personnel.

The introduction of a new technology in telemedicine is also an investment. It includes a variety of costs including software, hardware and training costs. Introducing and training the staff on new technology is a notable investment, and hence many organizations like to cut on this cost as much as possible.

In order to minimize the changes that the introduction of the system will cause on healthcare personnel, in our future work we will investigate how telemedicine consultation can be linked into physicians' day-to-day work patterns. In particular, we will consider how the functionalities of the Consultation Portal can be integrated with other e-health tools used by the physicians.

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Prescient Profiling – AI driven Volunteer Selection within a Volunteer Notification System

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***Abstract*—A Volunteer Notification System (VNS) is a promising approach to integrate laypersons into emergency medical services (EMS). In case of a medical emergency, a VNS will alarm those potential helpers who can arrive on scene fast enough to provide the most urgent measures until the professional helpers arrive at the victim. Whereas the basic requirements and criteria of a VNS have been discussed in recent publications, this paper will focus on the actual volunteer selection process and the underlying concept of Prescient Profiling. By using concepts of artificial intelligence, the available data is processed in order to generate an abstract digital representation of a volunteer and further enhanced to produce individual user profiles. These profiles will enable predictions on future decisions and the identification of behavioral patterns within the pool of volunteers. The goal is to provide an efficient algorithm for determining a highly sophisticated set of relevant volunteers for an ongoing medical emergency.**

Keywords-Volunteer Notification System; First Responder; Emergency Medical Services; Profiling; Artificial Intelligence

I. INTRODUCTION

As stated within a recent study by the clinical center of the university Munich [1], the average arrival time for Emergency Medical Services (EMS) on scene in Germany is about nine minutes. Whereas most medical emergencies do not involve an immediate life danger for the victim, during a Sudden Cardiac Arrest (SCA) the first minutes are of utter importance. The probability of permanent brain damage increases with every minute and a time interval of more than five minutes without treatment will most likely result in the death of the victim [2][3]. The severity of the time deficit generally correlates with the infrastructure a country can provide, resulting in intensification for less advanced countries.

One possible approach to provide the most urgent medical measures before the professional EMS arrive on scene is the implementation of a Volunteer Notification System (VNS) as discussed in [4]. The basic concept of a VNS is the integration of laymen and medical trained volunteers into the EMS by notifying those potential helpers who are, at the time of incident, "close" to the victim. Whereas the term "close" is suitable for describing the general idea, the actual process of selecting the relevant volunteers within an ongoing medical emergency requires, due to possible obstacles as e.g., rivers, traffic jams, or alternative transportation means, a sophisticated algorithm in order to ensure the best possible set of potential volunteers at any given time. Artificial intelligence (AI) offers a variety of methods in the area of problem solving [5] and for implementing self-learning systems [6] aiming to increase the quality of decisions by adaption over time. The possibilities of AI driven system within the scope of a VNS will be introduced within this paper.

The remainder of this paper is organized as follows. The difference between a simple and an intelligent volunteer selection will be discussed in Section II, whereas Section III will highlight the necessity of an intelligent approach by describing some non-trivial decision scenarios in which simple selection algorithms will provide flawed or inaccurate results. Section IV will therefor introduce the basic concept of (prescient) profiling within this domain as a suitable approach to enable an AI driven volunteer selection. Further research perspectives are discussed in Section V.

II. VOLUNTEER SELECTION

In case of an incoming emergency call, the responsible dispatcher will alert the professional EMS and – in case a cardiac arrest or any type of emergency that requires immediate treatment is suspected – trigger the forwarding of the information into the notification system [4]. The VNS will now decide which volunteers are to be alarmed. In order to prevent unnecessary notifications – hence, notifications that will immediately appear irrelevant to its recipient or notifications alarming volunteers without any plausible chance of reaching the victim in time – an efficient selection algorithm is required [7]. This algorithm has to forecast the approximate arrival time of an individual volunteer at the scene of the incident.

A. Simple Volunteer Selection

A simple solution for selecting volunteers is the implementation of a notification radius, defining a maximum distance around the place of incident and alarming those volunteers who are within this radius. This approach will provide a set of helpers who are geographically close to the victim, but will they also arrive on scene faster than potential helpers outside the notification radius? To forecast an individual arrival time, more information is required on both,

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the volunteer and the environmental details affecting her at the moment.

B. *Intelligent Volunteer Selection*

Whilst the actual distance is an important parameter to be considered when deciding if a volunteer should be notified or not, it does not necessarily determine the volunteers' time of arrival at the scene. Due to impassable obstacles (e.g., highways or rivers), the beeline calculation does not offer a suitable background for estimating the arrival time, but even the consideration of up to date map material – like so enabling a shortest way calculation – will not provide sufficient information without additional assumptions.

Thus, the type of movement, the physical performance of a volunteer and the current traffic situation, all have a direct influence on the approximate traveling time and thereby on the time of arrival. Furthermore, limiting the relevant decision parameters to merely distance or traveling time appears inadequate and secondary criteria apply; e.g., the potential volunteers' medical expertise, her individual knowledge of the area and the current situation this volunteer is involved in. An efficient algorithm hence has to consider a broad variety of available information on each individual volunteer in order to generate a reliable set of potential helpers [7][8].

III. SCENARIOS

The necessity of an intelligent volunteer selection is demonstrated by multiple non-trivial decision scenarios, as illustrated in Fig. 1. The place of incident is close to a railway station (the red bar located on the railway tracks). Leaving heuristics aside, implying to have only five volunteers in total, the most promising of these are to be notified. The use of a simple volunteer selection – as introduced in Section II – will result in the following set of volunteers (as marked within the red area) that will be alarmed:

- the pedestrian just north of the incident,
- the volunteer in the car (on the highway), and
- the pedestrian in the park (close to the river).

An intelligent volunteer selection will demand further information on each potential candidate than just her current location. The following section gives a short discussion on each single volunteer and the required additional information to decide reliable if the volunteer should be notified or not:

1) The pedestrian just north of the incident is geographically the closest volunteer. A straight road connection and no obvious obstacles result in minimal requirements on travel speed or physical performance. This candidate appears a solid choice no matter further assumptions, but eventual circumstances could prevent her from arriving in time, e.g. she might be traveling with her children which she picked up a few minutes ago; just like she does every day at this hour.

2) The volunteer in the car is the second closest, but should she be alarmed? Depending on the direction the car is driving and the distance to the next highway exit, this volunteer will most likely have no option to arrive on scene in time.

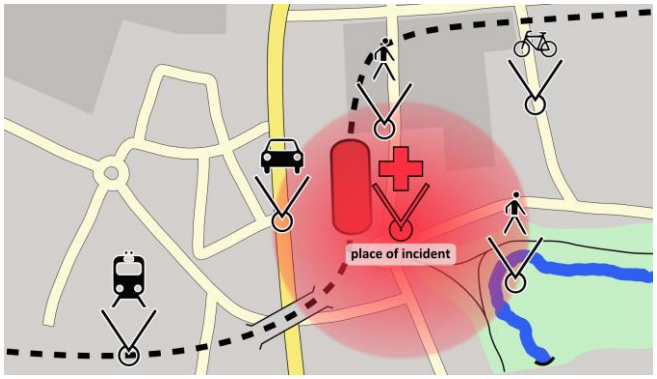

Figure 1: Non-trivial volunteer selection

3) The pedestrian in the park is blocked by a river. This volunteer will only arrive in time when the next bridge is within reach. Furthermore, with the park being a green zone with limited map material available, it might only have a single exit that is far away.

4) The volunteer riding the bicycle is outside the notification radius, but due to traveling speed and possible short-cuts, she might arrive on scene fast. Parameters like one-way roads or uphill/downhill will influence the arrival time but generally she appears a good choice for notification and compared to a car with the same distance, she will not require a parking place and isn't slowed down by high traffic (which occurs more often around stations).

5) The last volunteer (in the train) appears to be far away, but assuming that the train rides in the right direction and will also stop at the next railway station, she might arrive on scene earlier than any of the other volunteers.

Within the illustrated scenarios, the notification radius resulted in a set of three volunteers, from which probably only one has a realistic chance to arrive at the victim in time. Moreover, potentially highly valuable volunteers have not been considered for notification. The given examples are just a small selection of possible scenarios in which no simple answer on if to alarm a specific volunteer exists.

In order to determine the best possible set of volunteers for an ongoing medical emergency, an efficient selection algorithm is required which postulates the availability of a complex knowledge base. A variety of parameters is to be collected, processed and evaluated, forming the digital profile of an individual volunteer.

IV. PROFILING

The term profiling has been frequently used over the last years in different research areas. Within the field of information and computer science it is mainly used in conjunction with the terms: program behavior [9][10], (web) user [11][12], network [13], or social media [14].

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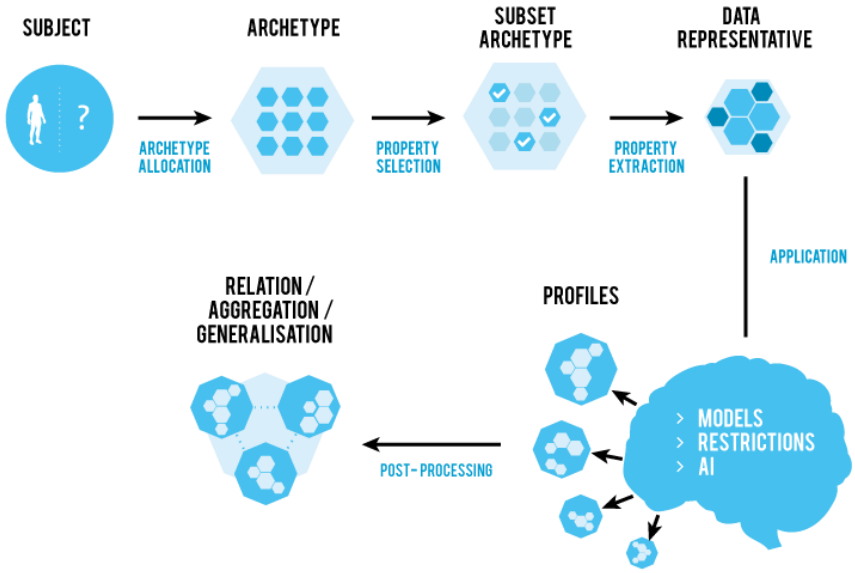

Figure 2: Sub-processes of Profiling

A. *General usage*

Generally, profiling is defined as "the act or process of learning information about someone based on what is already known" [15]. This definition is vague concerning the act or process used to obtain information and does neither define the kind of information retrieved nor its origin. Due to this lack of an exact definition, an appropriate assignment of methods, techniques or technologies regarding profiling is not possible without clearly distinguishing between the various implementations and their individual context.

In order to specifically define the process of profiling that will be introduced within this paper, it is necessary to present a definition of what profiling describes within the scope of an intelligent volunteer selection in correspondence to aspects of information and computer science. Furthermore, the requirements and outputs that are to be expected by the application of profiling have to be defined.

The term profiling is hereby not to be confused with a profile. A profile is commonly defined as "a brief written description that provides information about someone or something" whereas the verb to profile is defined as the action "to give a brief description […]" [15]. This definition defines a profile as the result of a process generated to describe someone or something, i.e., an abstract representation of the profiled subject.

B. *Definition*

Profiling describes the process of generating profiles from obtained data, associated to one or multiple subjects. A profile itself is a non-empty, finite, ordered tuple with a positive number of elements. Each of these elements consists of a finite number of values corresponding to its individual domain. The process of profiling is divided in multiple sub-processes, which are illustrated in Fig. 2. The various terms describing these sub-processes and the different artifacts which are their results, are shortly described as follows:

1) Subject: A subject describes "what" is actually being profiled. Within the VNS, the subject will be a registered user (a human being) but in general, anything can be profiled; e.g., a life-form, medical symptoms or an abstract stream of data. This definition stays in correspondance to the term subject as reffered to in [16].

2) Archetype Allocation: Due to the generic background of the profiled subjects, the system needs an approximate "idea" of what kind of subject it will deal with. The archetype allocation describes the process of mapping a subject to a specific archetype.

3) Archetype: The archetype is an abstract representation of anything that can possibly be profiled. It defines the maximum set of properties that are available on a specific subject. Archetypes can consist of other archetypes as elements; e.g., a human can have a car or children as elements in the archetype, whereas children are themselves represented as humans within this set.

4) Property Selection: After a subject has been mapped to an archetype (or a combination of archtypes), it has to be decided which of the available properties are of importance for the profiling process. While it is theoretically useful to support algorithmic selection and re-adjustments in this selection process by implementing a suitable learning strategy, a simplified approach will only process the property selection once, i.e., the properties representing the subject are not modified during the profiling process.

5) Subset Archetype: After the relevant properties have been selected from the archetype, the structure of the digital representation of the profiled subject is determined. This artifact is referred to as subset archetype and constitutes the base of the following data representation.

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6) Property Extraction: The property extraction describes the process of collecting the data (e.g., trough available sensors or automated systems). The selected properties of the subset archetype will be filled with values. This process will result in the creation of the data representative.

7) Data Representative: The data representative conforms to the abstracted, digitalized description of a subject. It consists of the selected properties of its subset archetype and holds the raw data from occurred property extractions. This term is not the same as a data subject introduced in [16] but instead differentiates due to its raw data characteristic.

8) Application: This process is defined by the application of different models, processing the data representative . The processing will lead to a profile of the data representative. Possible models are introduced in the upcoming section.

9) Profile: A profile is a generalized representation of the data representative. The degree and direction of the generalization is defined by the context of the profiling process, i.e. the applied models.

10) Post-Processing: This step describes the generic approach of applying various methods to the existing profiles. Examples are clustering, association analyzes, or the identification of relations between profiles.

11) Relation/ Aggregation/ Generalisation: This artifact describes the result of the post-processing. Examples for this category are sets of profiles which are aggregated by associations or relations between them, or group profiles representing identified group properties.

C. Application models

In the context of behavioral predication, application models are generally based on theoretical rational behavior [17], bounded rationality (i.e., psychological models) [18], or on models that are based on observations which are characterized by methods of machine learning algorithms [19]. Beside the sole implementation of a single approach, a combinatorial aggregation of different types of models is possible. Recent research states that especially the use of hybrid models which are based on machine learning, but add features from psychological models, performed significantly better in various domains [20]. An alternative process is the sequential application of different models to a single data representative in order to retrieve specific properties of that profile.

D. Prescient Profiling

With the data representative uniting the digitalized properties of a subject that were collected over time, a base for further processing is available. Applying different models (as discussed above) will result in individual profiles that enable various operations; e.g., clustering and the evaluation regarding specific criteria. This process conforms to the definition of profiling as given in Section IV, while prescient profiling may be considered "the next step" on top of this basic definition, using the profile(s) to generate new insights and therefore enable enhanced capabilities.

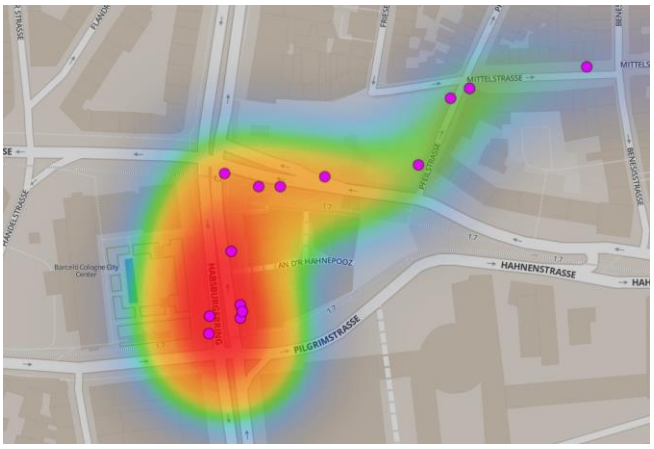

Figure 3: Location heat map

Implying a learning system approach, thus, a system that uses methods of AI to learn from past observations and thereby identifies trends and patterns, will not be limited to analyzing the historical values but instead will have the ability to make predictions. This states an enhanced definition of profiling. The term "Prescient Profiling" therefor refers to this special type of profiling, aiming to make reliable predictions on both, the value of individual properties and on a profile itself.

E. Profiling within the VNS

In the context of a VNS, the subject of profiling will be the volunteer (i.e., the registered user). The corresponding archetype is human with the following, exemplary properties to select from: gender, height, weight, age, location, number of children, type of car. Within the property selection, only the location is selected as property that is filled with data during the property extraction process. This extraction will occur automatically, i.e., the mobile phone will continuously push updated information on the volunteer's location to the VNS server. All incoming location updates are stored in the data representative of this volunteer and applying specific models will generate different types of profiles. One suitable approach is the generation of a so called heat map [21] as part of the resulting profile. This location heat map, as illustrated in Fig. 3, describes the current whereabouts of the volunteer to be profiled as probabilities, rather than a single valid location; the calculation is based on the available location data from within the data representative (i.e., the purple dots).

By generating profiles of different volunteers and applying post-processing methods, e.g., clustering or pattern recognition, aggregated profiles are being created, representing the relation between different volunteers and their corresponding heat maps. In addition, trends and progresses in the development of individual heat maps can

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be analyzed in order to create group profiles or enable various predications.

V. CONCLUSION AND OUTLOOK

Whereas a basic VNS implementation is able to notify volunteers in the closer vicinity by using simple selection algorithms, various scenarios have been discussed in which an efficient volunteer selection will require the consideration of additional factors. The concept of profiling has been introduced as a suitable solution within this context, aiming to generate profiles of individual volunteers. This is achieved by creating a data representation of the profiled subject, based on specific parameters that are selected from an archetype definition within the property selection and filled with data during the property extraction process. The application of different types of models, integrating various concepts of pattern recognition and machine learning in order to identify behavioral patterns and coherences between volunteers and individual properties, describes an enhanced process of profiling that has been introduced as "Prescient Profiling", utilizing the various profiles to enable predictions on individual subjects or groups.

The research focus of the near future will be the actual implementation of the machine learning approach and the development of corresponding models. The explicit application of Prescient Profiling within the context of the VNS needs to be analyzed, developed and evaluated. With an integration of the VNS system into the emergency workflow of regional EMS partners planned for the beginning of 2014, promising possibilities for an efficient data assessment are being created; enabling benchmarks and comparisons of various selection models in different emergency scenarios and thereby producing academic results on the efficiency of an AI approach for volunteer selection in medical emergencies.

ACKNOWLEDGMENT

This paper is based on work done in the INTERREG IVa project EMuRgency (www.emurgency.eu). The project is partially financed through the European Regional Development Fund (ERDF) and co-financed by several regions of the Meuse-Rhine Euroregion and partners of the EMuRgency consortium.

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A Health Virtual Community Model

A Bottom Up Approach

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***Abstract*— This paper presents a model for Health Virtual Communities (Health VCs) based on a case study of a Health VC for chronic disease management designed for rural and disadvantaged communities in a developing country. It provides an analysis of the components needed in the Health VC and the necessity of a flexible design. The model provides a list of characteristics that a Health VC design should have in order for it to provide a viable, value-added experience to users who have heterogeneous capacities in terms of access to Information and Communication Technologies (ICT). It establishes a first attempt towards a framework for a Global Health VC analysis and design.**

Keywords- Health; Global Health; Online Communities; Modeling; developing countries; rural eHealth; LMIC.

I. INTRODUCTION

Since its inception, the Internet provided a great opportunity for people to meet online and form the first Virtual Communities (VCs). VCs drove a lot of research to understand the way people cooperate in them and the challenges and opportunities they provide. Researchers explored the possibility of use of VCs in identity building [1], and looked into the design issues involved in connecting people together [2] to drive trust [3-5], and enable reciprocal awareness [6]. Besides, the ability of a community to generate and use knowledge was investigated [7, 8] and diverse VCs were implemented, such as, human rights monitoring [9]. Health Virtual Communities (Health VCs) were not late to emerge and to carry their own problems and prospects [10, 11].

Global Health Virtual Communities and Challenges have recently been investigated and a first attempt towards a model for Global Health VCs was proposed by El Morr [12]. In this paper, we will start with a background about health virtual communities (Section II). We will then introduce a previously suggested model (Section III). We will then explain the project (Section IV) and describe how we did apply it in global health project where the team had to build a health virtual community to enhance equity in the supply and demand of primary health care services in Lebanon and suggest its modification to the model based on experience (Section V). We will then conclude the paper (Section VI).

II. HEALTH VIRTUAL COMMUNITIES

Health Virtual Communities can be defined as a group of people using information and communication technologies to deliver health care services; they cover a wide range of clinical specialties, technologies and stakeholders [13]. The stakeholders and participants of Health VCs are health care providers, educators, patients, and health professionals (e.g. nurses). Health VCs can be divided into three types depending on the objectives they aim to achieve; a VC can be (1) *Professional Centered*, (2) *Patient Centered*, *or (3) General Public Centered*.

Examples of *professional centered* VCs include knowledge exchange and research teams [14-17]. Members in these communities are health professionals that interact and work in virtual teams in order to exchange knowledge and create new knowledge if possible [7]. Professional-Centered VCs provide support for healthcare professionals in their activities.

Patient centered VCs involve usually patients, their family members, and a health professional from the community [18-20]. Patient centered VCs permit professionals-to-patient and patient-to-patient communication and support [5, 21-26]. Indeed, health care professionals can form virtual teams to provide care and support in disease management; besides, individuals diagnosed with the same chronic [27] or life threatening disease, or undergoing the same treatment, can exchange and share health information and personal stories. Thus, a patient centered VC ensures continuity of care through the exchange of messages and resources. Patient-centered VCs facilitate care delivery mechanisms to provide support for patients while they are away from the point of care. Patient support is paramount; its lack has a serious impact on health [28-31].

General public centered VCs are open and include educational services, discussion forums, and access to health information. The aim would be for the patients to be in charge of their health care by personal action (i.e., manage their disease) [32]. Many research projects demonstrated the importance of education in empowering patients [32-39]. Some general public VCs are disease specific while others target a specific social group (e.g. women) [40-42]. General

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public VCs aim to disseminate knowledge to the wider population, promoting self-management of healthcare and empowering patients [32-39, 43] .

III. A VIRTUAL COMMUNITY MODEL

El Morr has suggested a model for collaborative virtual communities [10, 44] and developed it later to encompass global health virtual communities [12], and suggested a model shown in Figure 1.

Figure 1. A Global Health Virtual Community Model

The model stipulates that a global health virtual community should have the following fourteen features:

The ***degree of mobility*** specifies if the VC members are 'still or 'mobile'.

The ***degree of virtuality*** specifies if an encounter between members is 'physical' (members are physically in the same place) or 'virtual' (members meet online).

The ***degree of cooperation*** specifies if the members' awareness of each other passes through a simple notification mechanism, or if the members 'collaborate' dynamically and actively on a common aim.

The ***degree of uniformity*** specifies if the members are extremely 'homogeneous' (the VC is a community of practice) or 'heterogeneous' (having different occupations).

It should have an ***inclusive design*** that supports diverse users, and conduct a ***participatory approach*** to encourage their participation. The global health VC should be ***supportive*** to users, ***workflow adaptive***, and should adapt its behavior (interface) to the different kinds of users by being ***profile sensitive*** and therefore personalizable.

The ***policy sensitive*** aspects reflect the need for the VC to be able to adopt different security, privacy and trust mechanisms.

A successful global health VC should be ***culturally adaptive*** *and* ***environmentally adaptive*** reflecting different environments' priorities and contexts.

One of the challenges is for it to provide ***infrastructure adaptive*** features by being able to accommodate less expensive and advanced technologies. Finally, it should provide means to share resources between stakeholders acting as a ***value catalyst*** tool.

IV. THE PROJECT

The collaborative research team includes researchers from the American University of Beirut, Ministry of Public Health (MoPH) in Lebanon, the United Nations Relief and Works Agency (UNRWA), York University, and University of Toronto.

In Lebanon, a Low-Middle Income Country (LMIC), chronic diseases constitute an important public health problem accounting for around 84% of all deaths based on the 2008 estimates of the World Health Organization (WHO) [45]. Specifically, age-standardized death rates from cardiovascular diseases (CVDs) and diabetes reached 404.4 and 262.7 per 100,000 individuals [46]. This burden of chronic diseases is further aggravated in the context of disadvantaged populations in many of the rural areas and Palestinian refugee camps in Lebanon. For instance, residents of underserved rural areas in many regions in Lebanon, as well as the Palestinian residents in the refugee camps, lack equitable and sustainable access to modern care services for chronic illnesses. Non-governmental organization (NGO)-run primary health care centers and dispensaries are considered the only facilities available in the aforementioned underprivileged rural areas and often suffer from limited availability of resources [47].

This project constitutes an eHealth [48] proactive integrated approach that couples community-based and health care initiatives to managing chronic diseases.

Ten Primary Health Care (PHC) centers located in rural areas and enrolled in the Lebanese Ministry of Public Health (MoPH) PHC National Network (Network) and six United Nations for Relief and Works Agency (UNRWA) centers will comprise the study population. The ten MoPH and six UNRWA centers are randomly assigned into the intervention and control groups (five MoPH and three UNRWA centers in each for eight intervention sites). Each PHC center belonging to the Network has a defined catchment area with an average of 30,000 inhabitants [49]. The ten participating MoPH centers will be chosen from five rural areas in Lebanon (2 centers from each area – one as control and one as intervention).

A. *The Intervention*

The eHealth intervention will have two components:

1) **PHC center-based** in which eHealth will target the physicians (supply) and patients suffering from diabetes and hypertension (demand) treated in these centers, and
2) **Community-based**.

1) *PHC center-based*

a) Health Provider Side

The Provider side eHealth intervention will comprise two main initiatives:

(1) Online modules for treating diabetes and hypertension focusing on (a) clinical guidelines and (b) physician-patient communication strategies (smoking cessation, increasing compliance, etc.).

(2) Online forums and Frequently Asked Questions (FAQs) mainly dedicated to peer-to-peer knowledge sharing of treatment and communication techniques, as well as a database of Questions and Answers (Q&A) on such techniques.

b) Patient Side

On the other hand, the Patient side eHealth interventions will comprise one main level: the current patients will receive cell phone text messages or short message services (SMSs) that include simple weekly medical information about their respective disease and the importance of compliance and generic reminders of appointments and regular physician follow-up.

2) Community-based

A community-based intervention will be conducted that includes screening for diabetes, hypertension and obesity in the catchment area of each of the eight (5 MoPH and 3 UNRWA) intervention centers. Allied health professionals (nurses or medical technologists) will perform household screening of individuals using a purposefully designed chronic illnesses screening kit that measures the following components: (a) blood glucose level, (b) blood pressure, (c) waist circumference, and (d) Body Mass Index (BMI). The results of the four screening tests will be remotely entered on a software application alongside other demographic data pertaining to the individual including name, gender, age, and others. In the event that the individual is identified to have symptoms of one or more of the three screened diseases, the individual will be offered an appointment with a primary care physician in the PHC intervention center of the corresponding catchment area. The appointment will be scheduled remotely and during the visit through a specifically designed application linked with the PHC intervention center pre-loaded appointment sheet. In addition, patients will be offered an on-the-spot brief Disease Self-Management Education (DSME) provided by the allied health professionals. The DSME interventions will aim to strengthen the patients' capacity, to enhance their quality of life and to prevent acute and chronic complications, while keeping costs acceptable.

B. The eHealth Solution: Virtual Community

To ensure an eHealth solution that works for all the centers on both the providers' and the patients' sides, a health virtual community was set in place. The virtual community aimed to provide the necessary tools on an already existent physical connection between the healthcare community centers and the MoPH. The VC design included:

1- A website that allows the healthcare providers to access the FAQs and send their questions to the moderator who will reply to the requests by creating a new FAQ, if necessary. Moreover, the website publishes online modules for treating diabetes and hypertension focusing on clinical guidelines and physician-patient communication strategies.
2- A software module that allows the data entry for health clinical indicators; the module was integrated with the primary health care information system in place at the centers.
3- An SMS messaging system was designed to integrate with the module in order to send the patients' appointment reminders and weekly educational information (e.g., medications, compliance).
4- The appointment scheduling system was designed as a software application. The software will also run educational presentations about the diseases.
5- The educational system to be delivered to the potential patient during screening was designed to be delivered on in an electronic format (notepad).

The overall VC system design is presented in Figure 2:

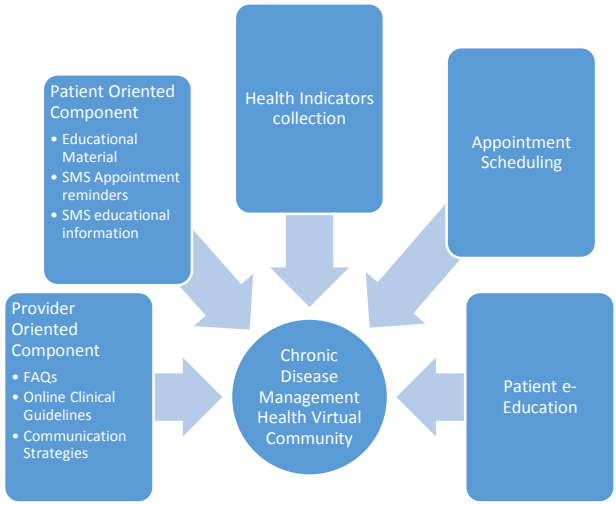

Figure 2. A Health Virtual Community Model for Chronic Disease Management in rural and disadvantaged communities.

V. A HEALTH VIRTUAL COMMUNITY FOR EQUITABLE CHRONIC DISEASE MANAGMENT

We launched the health virtual community project in September 2013 and we applied the VC characteristics, as shown in Figure 1, as a structured tool to explore the high-level system's requirements, from a VC standpoint. We provide here a summary of the system analysis process as a case study to discuss the model and we propose an updated version of it.

Degree of Mobility: Most of the parts of the system need not to be mobile. The only mobile part required will be to provide the community field workers with a mobile patient screening and scheduling system. Thus, we adopted a *hybrid* approach containing a fixed as well as mobile component. Therefore, we suggest to update the degree of mobility we

have discussed above, to include not only still and mobile options but a *hybrid* option as well.

Degree of Virtuality: The community is virtual since members will have to work remotely.

Degree of Cooperation: In our project, a tight cooperation is required between community members in order to ensure the right scheduling and patient care delivery at the right time by the right person. Nevertheless, the scheduling software present in the health community centers was not able to support remote access from the field workers' laptops; consequently, we opted for an off-line solution where field workers have to schedule screened patients off-line and then to synchronize their appointments once they reach the health care center they are affiliated to. In case of conflict, the field worker would call the screened patient to reach an alternative appointment.

Degree of Uniformity: The community is heterogeneous since it involves doctors, nurses, field workers, researchers, data analyst, etc. Each would require special tools to work. The model in Figure 2 shows the main aspects of our VC. One component is patient oriented and used by patients (SMS messages), another one is health provider oriented and used by providers (online forum and FAQs). Field workers to schedule appointments will use a component; another one will be used at the healthcare centers to collect patient indicators. Regarding the patient e-education material, even though Lebanon has a high penetration of internet (52%) and cell phone use (3,350,000 mobile-cellular telephone subscriptions, equivalent to 78.65 subscriptions per 100 inhabitants)[50], smart phones were not judged to be a good tool in the rural communities and therefore we decided that the field worker leaves a printed material with the screened patients. That last solution makes the material accessible in an easy way known to all.

Inclusive Design: The design was inclusive since its inception. The doctors and community field workers will be consulted from the beginning of the project to ensure that the clinical guidelines conform to their expectations in terms of language and presentation. That ensures an inclusive design providing better chances for adoption by end-users.

Participatory Approach: The community of healthcare providers will be using the system in their work environment. We expect that they will find interest in participating in the forum and accessing the FAQs. We will measure the participation via embedded software tools that will provide some participation indicators (number of hits, number of logins, number of questions, etc.).

Supportive: A coordinator will be supporting the members of the VC.

Workflow Adaptive: The workflow was local, decided by the MoPH, and therefore was not an issue in our project.

Policy Sensitive: The privacy and confidentiality laws and regulations were implemented based on the standards set by the MoPH. The appointment data are stored locally in each community center. The MoPH owns and manages the clinical software run in each center and provides remote update on it.

Culture Adaptive, i.e., **culturally sensitive:** The researchers used English and Arabic and were fluent in both. Field workers will use mostly Arabic to communicate with the local population in the rural areas. The culture at work was framed by the information system in place set by the MoPH. No special adaptation will be made to local cultures.

Environment Adaptive: There is no "environmental" issue. The research tackles many diseases that have the same prevalence across the country.

Infrastructure Adaptive: The eHealth research team decided on many delivery strategies for the educational modules. During the screening, a notepad (e.g., electronic pad) will be the delivery means for all patients scheduled for appointment. However, since 4G networks have been penetrating the market in a rapid pace, a software that delivers the same message is also scheduled for development, ensuring many delivery channels for potential patents. The SMS messaging system will be delivered by a local company; it has Application Programming Interface (API) that allows the designers to embed the SMS messaging strategy in the VC.

Value Catalyst: A training session will be designed in order to train doctors and field workers on the clinical guidelines and their benefit, the value of the screening process and the input of the clinical indicators (during the intervention).

Based on our analysis, we find that the model proposed in Figure 1 is very useful in capturing the VC requirements; it gives an accurate high-level description of our project. However, we propose to include a "hybrid" component in the description of the degree of mobility; in our case, some aspects of the VC are fixed while others are mobile. We suggest that we add a "synchronous/asynchronous" aspect in the degree of cooperation; in our case, the cooperation is neither fully dynamic nor fully based on a messaging mechanism; for instance, the scheduling will occur in an asynchronous way (synching will occur once the fieldworker reaches the community center) without neither involving a messaging mechanism nor a dynamic collaboration.

Profile Sensitivity: Taking into consideration the limited use of the VC, there were no disparities in users profiles. Different users will access different parts of the VC; consequently, the user interface adaptability to user profile was not an issue.

Finally, we found it more useful to classify the different features presented in Figure 1 into categories. The result is shown in Figure 3.

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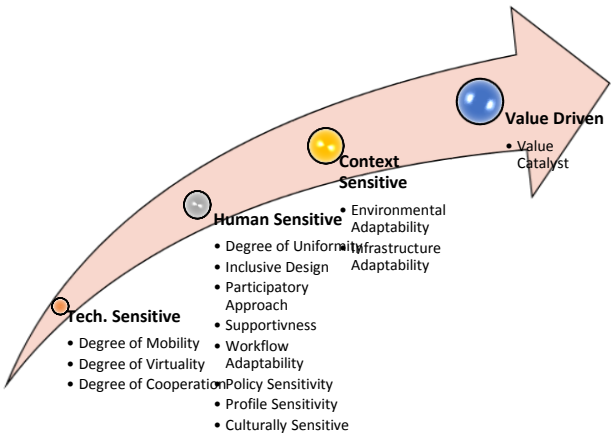

Figure 3. A Health Virtual Community Model

VI. CONCLUSION

This paper presented a previously established health virtual community model and analyzes its components based on a research project in a developing country. Through the analysis and design phases of our health VC project, the model proved to provide a useful way that helped to identify a suitable course of action and to describe its different components. It finally suggests two important modifications to the mode and provides a different, more system design friendly, classification of its components.

In the context of the Lebanese public health, the project is expected to enhance the equity in access to the chronic disease management in poor and underprivileged areas in the country, through the patient-oriented component (e.g. SMS reminders and educational information). The provider-oriented component would enable the caregivers to establish better communication strategies with their patients, reduce professional isolation and enhance access to updated knowledge.

In the context of research in virtual communities, our model establishes a framework for global health teams to ask the right questions when they are in the analysis and design phases of a Health VC information system. To the best of our knowledge this is the first time we have a model for that purpose. The model needs to be verified and tuned during the next few months. Future research will fine tune the model, develop the Health VC and implement it. The Health VC will be used in day-to-day activities in the chosen centers and indicators will be collected in order to measure its impact on chronic disease management in comparison.

ACKNOWLEDGMENTS

This work was carried out with the aid of a grant from the International Development Research Centre, Ottawa, Canada.

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Experiences of the Elderly, their Relatives, and Volunteers of a Social Media Application in Monitoring of Wellbeing

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***Abstract*— In the spring of 2013, we conducted a qualitative field study where elderly people, their relatives, and volunteering friends used a new social media application (Comcare) that runs in an Android tablet computer, for a period of two months. Comcare makes it possible to communicate with one's own social circle. In addition, it enables relatives to monitor the everyday routines of the elderly. The research material consists of five circles, each one of which includes an elderly person, his relative, and a volunteer friend. The material was gathered in eight group interviews before and after the field study, and 15 personal interviews during the testing period. This article concentrates on results of the evaluation period by reporting experiences of using the application, social support and feelings of safety.**

Keywords–elderly; social media; user experience

I. INTRODUCTION

Social media has made a breakthrough among the young, working age, and partly also among pensioners. Social interaction has transferred more and more to the Internet and concurrently the time used with a computer has grown significantly in the time span 1999–2009 among the age group 10–64 [1]. Social media continues to expand its popularity among all age groups. Even though young adults (18–29 years) remain to be social network mass users, it is notable that the rate of usage growth has been faster in older age groups in recent years. For example, in the past two years, social media use among Internet users age 65 and older has grown 150 % between April 2009 and May 2011. Also during this same period social media use by 50–64 year-old Internet users doubled from 25 % to 51 % [2].

Use of social media can improve the quality of life in many ways as the psychological well-being and perceived well-being do not necessarily require professional help, it also can be achieved through the support given by friends and other related parties. Social support is found to have an indirect link to the subjective health experience through psychological effects. [3]. Sense of community is based on a membership i.e. the feeling that one belongs to a group and a shared faith that commitment on togetherness is given by the group [4]. Social support and connections to the community are important as loneliness forms an important health and safety risk for the elderly. Thus, interaction with other people has an increasing role in preventing loneliness [5].

Although high degree of acceptance concerning the ambient assisted living (AAL) has been found, and the system would likely make elderly people feel safer and more secure in their homes, the main concern still is how it will impact their daily lives [6]. It is suggested that relevant factors to the use of in-home monitoring technologies are where, when and in which situations user is monitored. Also seniors' perceptions of privacy related to these technologies are highly contextual, and influenced by psychosocial motivations [7]. There is some evidence that physical spaces and environments affect the acceptance of monitoring technologies [8][9].

Motivation for this study are findings of problems caused by the loneliness of the elderly, the breakthrough of social media, pressure to rise costs of social and health related services, and the need to add to collaboration between operators in the third sector and public sector, home care services. Third sector volunteer work e.g. friend services, play a significant role as a support to other home care services. In addition, new operational models are needed for volunteer work, in order to attract the younger generation, spending much of their time with the social media, to act as a supporting group for the elderly, and to direct some of the time they spend in the social media also towards taking care of the elderly.

Inspired by the aforementioned challenges a social media application (Comcare) was developed and tested for a period of two months. In this article the attitudes and experiences of the elderly of the first test period and user experiences are assessed from the perspective of the elderly, their relatives, and volunteer support persons. Extra attention is paid to the experiencing of benefits, feeling of safety, communality, and social support.

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II. COMCARE SYSTEM

The main idea of the Comcare system is to form a bi-directional and equal care-giving community to take care of an elderly person. Comcare is a system and an application of social media working in an Android tablet computer [10], that is primarily meant for daily contacts and relaying of images and for monitoring of everyday routines (Figure 1).

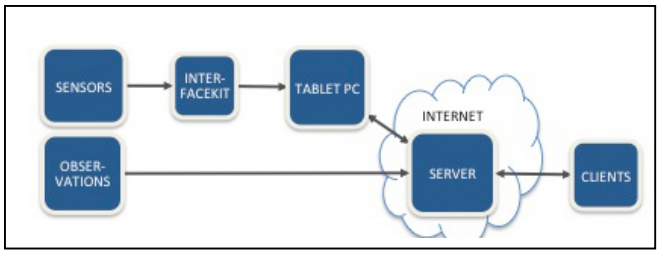

Figure 1. Comcare system architecture.

Comcare mediates updates written by the elderly themselves, through sensors by a door of restroom and door of bedroom, or members of the circle. Hence, the system enables the monitoring of everyday routines through the sensor-relayed data and by relatives belonging to the circle. The elderly can switch off the sensors at any time by pressing a button on user interface kit (Figure 2). The system shows all the output information to the elderly in the same way it is shown to the recipients. However, the updates are shown in different manners to the members of the circle depending on if the member belongs to the relative or the volunteer's circle. Relatives are shown the messages the way they have been written, but volunteers only receive the activity information. The sending rate of activity information depends on the setting of the monitoring mode. The settings choices are: once a day, four times a day, or continuously in real time. All members of the circle are able to send messages with the elderly, and also send images through private messages. The application did not include talk or video connection.

Figure 2. Comcare application and user interfacekit for sensors

III. MATERIAL AND METHODS

Five elderly people (three females and two males), five relatives, and three volunteer friends took part in the study. One volunteer was involved in two circles as volunteer friend. Table 1 shows the data of the partaking people. Emphasis in the qualitative analysis of the material was put on the experiences of the elderly, but also views of the relatives and the volunteers have been taken into account. The mean age of the elderly was 75.6 years. The elderly were volunteered customers of local voluntary friend service. The material consists of eight group conversations and fifteen individual interviews. The five first group conversations were held before the test period with the participation of an elderly person, a relative, and a volunteer. The three group conversations after the testing gathered together the elderly, the relatives and the volunteers, all in their own group conversations. The interview material was transcribed and the contents were analyzed by grouping the findings according to themes. In this article the attitudes towards, thoughts and experiences of the Comcare system before, during and after the test period are examined.

TABLE I. THE DATA OF PARTICIPANTS

Comcare Circle	Participants			
	Number of participants	*Gender*	*Age range*	*Mean age*
Elderly	5	3 women 2 men	73–78	75.6
Relatives	5	3 women 2 men	25–52	35.4
Volunteers	3	3 women	58–66	61.3
All	13	9 women 4 men	25–78	60.8

IV. RESULTS

A. Stance on technology and social media

The elderly had little experience of computers and the Internet. Social media as a term was familiar to only one elderly person. The interview cast light on the term, telling them that it means communication through the Internet, where people share e.g. the newest everyday goings-on in their lives or images etc., and Facebook was mentioned as an example. After the description, social media was treated somewhat skeptically, and when talking about the pros and cons thereof, four elderly people introduced threats in the utilization of social media. Data security problems and straight scams were causes of concern.

> *"Remember that there (in social media) can be nothing shown about me" (K3H1, 234)*

The attitude towards monitoring technologies, such as surveillance cameras and movement sensors, ranged from a defensive attitude to approval. Especially surveillance cameras raised a conversation for and against. The target group for safety technologies was estimated to be people living alone and who are in a bad condition. The attitude towards one's own video monitoring was negative, or positive but reserved. Movement sensors and live camera with blurred images containing little information were more readily approved of than monitoring cameras relaying sharp images. Accommodation to the existence of monitoring cameras was seen as being possible, but at the same time it was emphasized that the location of monitoring technology

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has meaning in the action of being approved of. Monitoring cameras were not desired in e.g. in the bedroom. The overall costs of safety technology and services were also considered to be a factor in their approval.

"In the beginning it might be a little bit like, that you are being stared at, but well you get used everything you know, it will go away by time then, from your mind, so then you won't mind at all, because it is like for example the tolling of the clock on the wall, so if you haven't heard it, it takes time to get used to it, and then it fades to the background there" (K5H1)

B. First impressions and trial period experiences

The participants got the first contact to the Comcare system in the initial group conversation where it was introduced to them. After the introduction they were asked for a first impression, and they ranged from interested and excited anticipation, to an attitude of questioning one's own abilities of learning. The relatives and the volunteers considered Comcare to be at first sight simple and easy to use. The elderly were not confident of their own memory, or their own learning capabilities. In the preconceived evaluations Comcare was seen as beneficial means for communicating and bringing change into one's life.

"You have to say that in a way this was such a nice little thing and you play ((laughs)) play with these but when it comes down to a real situation then I think that you can get used to it little by little." (K3RK1)

At the beginning of the trial period two of the elderly people experienced the use of the system as an interesting adventure. The technical problems confronted diminished this excitement. Comcare also caused extra attention and trouble that one did not always want to commit to. On the other hand, through visits of friends and relatives the interaction was sufficient even without communicating through Comcare and for that reason, one of the elderly people experienced Comcare as being somewhat useless.

"Well, I wouldn't know, it is, in the beginning it was learning and exciting, and then in the end you felt a bit annoyed when you could not" (K1H3, 66)

An increase in communication, in addition to phone calls, was one of the things experienced as beneficial about Comcare. Some felt that communicating was more active through Comcare than earlier. Especially those of the elderly people, whose relatives did not live close by, and people that did not frequently communicate through phone calls, felt that Comcare was an easy-going way of communicating and share everyday matters. The elderly mentioned that Comcare had affected their wellbeing and made them feel good. In addition, Comcare was experienced as heightening the feelings of closeness and as cheering up everyday life.

"We talked quite a lot after all, in the morning, in the daytime and also the in the evening, what it was that popped into mind. It was nice tapping them and there it went and I for one liked it. It was really this like close communication, that you can't be bothered to make a call about every little thing." (K5KRK)

At the end of the trial period the sensors, and user experiences thereof, connected with Comcare were discussed with the elderly. All the elderly and their relatives and the volunteers thought that they enhanced feeling of safety. Somewhat surprisingly, none of the elderly partaking in the testing period did not feel that sensors were disturbing or stressing. Some of the elderly even completely forgot that the sensors existed. The elderly thought it was good that they could themselves control if the sensors were switched on or off. Disregarding this none of the elderly switched the sensors off during the testing period. Part of the elderly thought that the sensor in the refrigerator was useless, but especially sensors the outdoor and the hallway were regarded as important locations for the sensors. In the final group interview it was discovered that three of the five elderly had no notion where the sensor data is going, who deciphers it and who reacts, if there is an emergency.

"Well I didn't quite understand, that girl she said it many times that where this went when here there goes wires on the roof" (K3KRK)

The most active circles experienced most benefit form the testing period. Two of the most frequently communicating elderly-relative pairs told that using the system had brought about a refreshed mood and nice meaning to everyday life.

"So she might have been a bit more vital at that point ... that she wrote things like 'good morning' and 'I have eaten this and that' and 'now I'll go for the groceries'. But I think that in our family mother kind of liked it. (L1H1, 68)

Communicating and sharing everyday matters became an integral part of the daily rhythm that the ones using the system most became somewhat dependent on the application. After the test period this frequent messaging was missed.

C. Learning the use and some problems detected

Only one of the elderly felt that learning was easy without problems. The relatives' and volunteers' learning was quick because of their earlier experience of information technology, but the elderly being not used to using computers and touch screens, learning was more arduous and an ongoing personal support was longed for. Four out of five elderly people encountered various problems in learning the system. Although the system was designed as easy to use as possible, lack of prior information technology experience, the unfamiliarity of the Internet world, understanding the functioning logic of the system, and using the touch screen,

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caused a lot of problems. A part of the elderly, however, overcame the problems and learned it successfully.

"As for myself, I can tell you that it was a bit hard at the beginning. But when I got to learning or knowing that compute, then I thought this is so nice." (K3KRK, 36)

Using Comcare was not an especially positive experience to everyone because of sparsity of messages, usability problems, and a closed circle. Nevertheless the possibilities of social media were recognized and it was felt that a similar system could be of use to them. Difficulties in learning the use were regarded as being due to, among other things, one's own health. Hence, rare messages were sent and the system was experienced as useless.

"I feel, that as I am sick, that I'm too tired for that." (K4H3)

The elderly doubted their own ability to learn and remember the use of the system, and felt insecure as users. Although clarity and big enough texts and icons were tried to achieve, some of the elderly people had trouble observing some elements in the interface. Inexperienced users were puzzled, frustrated, and insecure, when confronted with usability problems. Writing with the comparatively small keyboard or using the touch screen also caused a lot of problems. Finding letters was also difficult, because they had no prior experience where they keys are in a standard keyboard.

"Now that it has laid there on the table I have felt that I should know how to use it too so it has made me nervous that no (K4H3, 37)

The elderly had trouble distinguishing public updates and private messages. This could have been caused by a lack of prior models of this kind of sharing or graphic user interface related reasons.

D. Experiencing sense of communality and a feeling of safety

Deterioration of moving ability had restrained everyday activities. When getting out of one's home had been hindered, many hobbies and keeping up a social network were abandoned. For this reason it was seen that Comcare offered a new possibility for social interaction.

"It is a form of socializing when you really can't get out of here. It is like you're under house arrest. I have to say it is like I'm under house arrest here." (K1H3, 19)

The difficulty of learning how the system works and technical problems had their influence on the fact that it did not add to the sense of safety with everybody. One elderly person suffering from recurrent loneliness got relief to his loneliness by using the system; another one could not overcome the problems in learning the system, and thus was not able to benefit from the system. Nevertheless some felt, that a communication channel like Comcare adds to the feeling of safety. Most of the users were ready to use Comcare or a similar system also in the future.

"So that you can contact already right away these ones close to you that this computer has connected with, yes that gives a certain sense of safety." (K5H3, 294)

Those of the elderly that used the system actively told that communicating with it had made them closer to their relatives. The relatives had similar experiences. Frequent communicating and sharing one's own matters kept up the sense of community. According to active users of the system, sharing small matters of everyday life increased communality. The threshold to write a message seemed to be lower than e.g. making a phone call, so even small daily matters were shared more.

"So well but it was so nice in the morning when you could tap good morning get up to your daughter and then again so like I am going for groceries now and now I am going out to look for some company though she then answered really what she wanted. (K1KRK, 40)

Only one of the elderly was satisfied with the number of people belonging to the circle, others would have more members to be involved. Communication possibilities were craved towards one's own family and friends, as well as being ready to make new acquaintances via the Internet.

"Yes and maybe meet new people. Think about me for example, I have been here since 56 and well, most of my generation are already there underground, underground. (K1H3, 129:130)

In addition to the sense of communality, the elderly who actively used the system, felt that they also get social support through the system. During the test period also the less active participants saw the system as a possible aid in giving and receiving social support.

"It would be quite handy for you, too, this kind of a gadget and I know, it is me after all who takes these gadgets, because I am forced to be alone somewhat much (K3KRK, 467)

More frequently contacting participants told of a rise in spirits and feeling more cheerful and vital. Although many elderly people would want and need to keep in contact frequently, many of them told that they do not want to be a nuisance. They did not want to bother family, neighbors' or friends with their own troubles or their need for company. Although the testing period was short, a part of the relatives nevertheless told that they were better informed of the everyday situations of their elderly next of kin. A frequent contacting rate was assessed to lower the threshold for asking for support and help.

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"I would believe that when that, the using, the threshold of using, lowers then well, the asking for help or things like that, is much more easier and quicker" (L5H1, 134).

E. The amount and nature of communication

The elderly testing the system actively experienced that keeping in contact with relatives and volunteers had been facilitated during the test period. The threshold of writing a message was lower than that of making a phone call, because the sender did not need to fear he was disturbing the recipient. You could send a message as quick as a thing to be shared sprang to mind.

"I thought it was good in a way that I could be straight (in contact) like this with him so I didn't always have to take the phone in my hand" (K3KRK, 75)

There was a wide variety in the rate of activity between the circles. The three most active circles read and sent messages several times a day. Between the other two circles the messaging was less frequent (Table 2).

TABLE II. NUMBER OF SENT MESSAGES

Messages	***Circle 1***	***Circle 2***	***Circle 3***	***Circle 4***	***Circle 5***
Elderly	197	189	16	23	96
Relatives	305	270	12	10	171
Volunteers	30	-	13	11	16
Total	*532*	*459*	*41*	*44*	*283*

Reasons for rate of activity were slow learning of the system and less interaction and slow answering. Some case everyday life was otherwise full of social contacts, so that the usage of the gadget was scarce. Most participants felt that the utilization of the system added to the overall amount of communicating, because it did not replace other means of interaction but supplemented them as an equal means of communication. An interesting observation is that problems in using the system also added to the amount of communication. Problems in use were discussed on the telephone of face-to-face with relatives. On the other hand Comcare had reduced the number of telephone calls with two of the elderly people.

"We were more in contact. Up till then it was only once a day he called me". (K1H3, 102)

Most of the participants felt that the usage of the system was mutual: messages were sent on both sides just about as frequently. Only one elderly person felt that others were more passive and slower than him, that it made the use of the system less sensible. One of the relatives felt the communication to be one-sided, because his elderly next-of-kin had difficulties in learning to use the system. When contemplating about the one-sidedness or mutuality of the communication the elderly bore in mind the different day rhythms of both the relative and the volunteers: they did not even wait answer for a message to be written during the day, but only after the working hours. The communication via the system was informal in nature. Messages were chat, sharing everyday matters, and catching up on things, and taking care of small things to be done.

"Well it is like hello, how are you" (K4H3, 73)
"Couple of times a week no more, when you don't have actual business then it's no use just to babble" (K2H3, 206)

The elderly actively using the system experienced the exchange of messages as a nice pastime, which came an integral part of daily routines. Some of the elderly people, although, got bored waiting for answers to their messages.

"It was a wish in our family, at least sort of on mother's side, that when she wrote something, so that I would instinctively be behind the computer right there and then and answer" (L3LRK)

It was a desire to be able to communicate with more people that it was possible during the testing period and, to an extent, there was a readiness to make totally new acquaintances. Talking was a more known way of communicating with the elderly than writing messages on the Internet, and writing on the tablet computer was to a part of the elderly quite slow, thus voice calls or video calls would have been a more quick way of communicating. On the other hand many answerers mentioned the down sides of video calls. It was not desired to always share one's own image with others. Video or voice calls would also be more confining than exchanging messages.

"*Or on the other hand if you are tired yourself, so you really can't be bothered with a video call, because there is a good time for a video call, so it is not that it is suitable for every situation" (L5H1, 74).*

F. Acceptability

Comcare was not experienced as being stigmatizing. The elderly were fine with introducing Comcare to other people. In the end of the testing period the participants were asked of their willingness to use the system in the future. Part of the elderly felt that the testing period was a positive experience and would have gladly continued using Comcare or a similar system. The costs of acquisition and maintaining of a similar system may, however, form an obstacle for the continuation of the utilization of social media.

"I regarded it as a reason to be proud" (K5KRK, 454)
"If I had the money, I'd surely get a computer straight away" (K1KRK, 142)

According to relatives and volunteers, how the elderly accept the social media application are influenced by easiness of use, and how one is able to grasp how it works, as well as full functionality and reliability. Also the price of

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the equipment and the use of the service were believed to be factors in accepting the system. Relatives felt it was important that in order to be approved of by the elderly person, he would have to be totally in control if he wants to use the service or not. In addition, it was mentioned, that the ability to integrate Comcare as a part of the equipment already existing would facilitate its introduction.

"So if it was in your own tablet, so if it was in something you already use, then it would be easy to start using" (L5H1)

Volunteers were interested and ready to make Comcare a part of their everyday work routines. They did, however, mention that approval would demand a clear model of action in emergency situations, and how the service would be integrated to daily work routines. In addition, volunteers thought it was important that leisure time and time for volunteering work can be clearly defined.

"This was easy because it was a test period, so you could count that it was over by a certain date so it was quite easy to commit yourself to this. But I don't know, if it would be quite, that it would be there all the time... that could cause problems." (A1ARK).

V. CONCLUSION AND FUTURE WORK

The results must be interpreted with caution due to the minor research sample. The overall attitude of the elderly towards safety technologies and sensor technologies was positive and approving of with certain reservations. The elderly person himself is to decide as to who, where, when, and how he is being monitored and what kind of information is received about him. The attitude towards Comcare was of initial excited anticipation, which turned into annoyance and distrust towards the system, as part of the messages did not go through. The functionality of systems should be unconditionally secure before being introduced, in order not to lose the interest and excitement over the new technology.

The sensors in Comcare were considered to be acceptable and giving extra safety, as long as their location is suitable and does not interfere with privacy. In general, there is readiness to use safety technology if one's own health so demands and if it is situated in spaces where privacy is not considered being under threat. Social media services designed for the elderly would seem to have potential to support elderly people experiencing loneliness, and also in supporting communality, and in supplying social support. The observation that the ones who used the system the most, benefited the most, is important. According to this study it is not reasonable to offer the application of social media to people that are not willing to share small everyday matters with others.

Based on the study it seems that Comcare was more considered to be a method of conversation, rather than as a safety technology. For these reasons the system was seen as to be applicable also for wider use among the elderly, as soon as the technical shortcomings are cleared. The elderly, who actively used the system, felt that they also get social support through the system. However, also the less active participants saw the system as a possible aid in giving and receiving social support. Although the attitude towards technology was quite positive, a shared common view was that the safety of the elderly, or anyone else for that matter, couldn't be left only to technology.

A successful introduction requires of everybody in the circle the will, and the desire, to share matters with others, because an active communication always calls for at least two participants. According to this work there would seem to be an order among the elderly for social media applications. Extra attention has to be paid for them to be easy enough to use, having a reasonable price, secure in functionality, and easily learned also to first-comers. The future work must concentrate on figuring out challenges of separating public status updates and private messages and on exploring of those reservations the elderly have toward safety technology at home.

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Protecting the Privacy with Human-Readable Pseudonyms: One-Way Pseudonym Calculation on Base of Primitive Roots

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Abstract—**Pseudonyms are used in medical data to protect the privacy of patients: Demographics like name, gender and age are removed from the medical data and are replaced by a unique pseudonym. Medical data with the same pseudonym belongs to the same person. A pseudonym should be random or at least pseudo-random and should not allow drawing conclusions about the identity of the patient. Random pseudonyms are not always possible and therefore must be somehow calculated out of an identifier of the patient, e.g., by hashing or encrypting the identifier of the patient. In this paper an alternative algorithm is proposed to calculate pseudonyms on the base of primitive roots. The algorithm guarantees a collision free pseudo-random distribution of the pseudonyms, but creates pseudonyms with a bit-depth that easily can be transformed to a human readable representation. This is important if the pseudonym has to be used (be read, be written) in a day-to-day workflow. The pseudonymisation algorithm acts as a one-way function if all of the calculation parameters are kept secret.**

Keywords-patient privacy-enhancing technologies; secure patient data storage; pseudonymisation; one-way function; primitive root.

I. INTRODUCTION

Pseudonymisation is a process where demographics and identifier of a person are removed out of an information record and replaced by a pseudonym. This step is demanded to protect the privacy of patients in cases of secondary usage of medical data, e.g., for research or statistical purposes. In these cases knowledge about the identity of the person is unnecessary and therefore must be protected against disclosure. In contrast to anonymisation, a pseudonym allows to link data from several sources to the same person, which helps to improve the quality of the research or statistics.

An example for the need of pseudonymization is the storage of medical data, samples, blood and urine in biobanks. Researchers are not interested in the identity of the person behind this material. But a pseudonym is needed to link the samples from the same person, which have been taken at different locations and during different collection events. The pseudonym will not only allow the linkage to the same person but also allows protecting the identity of the patient behind the sensitive data.

Concepts on how identities of patients and their pseudonyms are used and managed (including identity matching, identity vigilance, linkage of identifiers from different domains) to securely exchange data are discussed in many publications (e.g., [1] and [2]). These concepts are not in the focus of this paper.

Assuming, that all the problems of identity matching are solved, the pseudonym number or pseudonym string itself has to be calculated or determinate at one point. There are several options to create a pseudonym with a given set of demographics. Some of these techniques base on hashing or encryption of a unique identifying number of the person. Others simply chose a random number and link this number with the identity.

Things are getting difficult if the pseudonym must be short enough to be human readable and usable, which limits the number of effective bits of the pseudonym to approx. 32 to 40 bits (equivalent 6-8 chars). Current hashing and encryption algorithms work with 128 bits minimum. In that case, the outcome of the process must be cropped to the desired bit-length, which leads to an unpredictable risk for pseudonym collisions.

Adopted solutions that take the small number of bits into account (e.g., [3]) still base on techniques that are used in symmetric encryption or hashing algorithms like the Advanced Encryption Standard AES [4] or the Secure Hash Algorithm SHA [5] (permutation, rotation, transformation, diffusion). With the small bit-depth of the initial data and the missing of deeper cryptanalysis, it is difficult to estimate how secure these algorithms finally are and how difficult it is to re-compute the person identifier with a given pseudonym.

The solution described in this paper is based on asymmetric encryption techniques as it is used as a one-way trapdoor-function. Because the used technique is hard, the described pseudonymisation algorithm in total is also hard.

The paper is structured as follows:

In Section II – Methods, firstly, a short introduction into the mathematical foundations of primitive roots is given. Then it is shown that this approach can be used for the calculation of pseudonyms. The section ends with suggestions how to find a necessary primitive root and how the calculations can be implemented fast and efficient.

In Section III – Results, the bit depth of the secrets that are used in the pseudonym calculation is shown especially if these secrets are sufficient to protect the original person

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identifier. A special focus is made on the human readability of the pseudonym and the speed to calculate the pseudonym.

In Section IV – Discussion, potential attacks and re-identification risks are discussed and an example for the applicability is given.

The paper ends with a conclusion in Section V.

II. METHODS

The mathematics behind the pseudonym calculation of a person ID is based on primitive roots of prime numbers as it is used in the Diffie-Hellman protocol to ensure a secure key exchange [6].

A. Modulo operation (mod)

a mod b, with *a* and *b* being positive integer numbers is defined as the remainder of the division of the dividend *a* and the devisor *b*. The result of the mod operation is an integer value in the range from *0* to *b-1*.

Example: 112 mod 24 = 16 because 112/24 = 4 with the remainder 16.

B. Discrete logarithm

Having the equation:

$$b = a^i \bmod p, \text{ with } p \text{ prime}, i \in \{1..p-1\} \quad (1)$$

Then *i* is called the discrete logarithm, which is equivalent to

$$i = \log_a b \quad (2)$$

The calculation of *b* is easy but currently there exists no efficient way to find the discrete logarithm *i* with given *a*, *b* and *p*.

This statement is only true if *p* is big enough to make the use of pre-calculated solution tables impossible and if no pre-knowledge about *i* exists that allows reducing the search space.

C. Primitive roots

The property of *a* being a primitive root of prime *p* means, that

$$a^i \bmod p, \text{ with } i = 1..p-1 \quad (3)$$

results in all values of *1..p-1*, with no value double or missing. This property is relevant to create collision free pseudonyms.

Primitive roots have been used already a long time ago to create good random number generators [7]. Our algorithm uses this knowledge to introduce pseudo-randomness into the series of pseudonyms.

D. Adaption for the pseudonymisation calculation

With *k* bits that are reserved for the pseudonym, a prime number *p* should be chosen that in best case is the highest prime number lower than 2^k. With the given *p*, the interval of possible person IDs and pseudonyms is *1..p-1*. The numbers which are invalid in the *k*-bit number space are 0 and $p..2^k-1$. As an example: For *k=31*, the highest prime lower than 2^{31} is $2^{31}-1$. In this case, only *0* and $2^{31}-1$ cannot be used as person IDs or pseudonyms.

```
t1:= id XOR c                    // XOR with secret c
if (t1 in [0, p..2^k-1]):        // If out of range...
      t2:= id                    // ...reverse if necessary
t2:= (t1 * q) mod p              // Expand with secret p
i:= t2                           // This is the exponent
b:= a^i mod p                    // The main calculation
t3:= b XOR d                     // XOR with secret d
if (t3 in [0, p.. 2^k-1]):       // If out of range...
      t3:= b                     // ...reverse if necessary
t4:= t3 << s                     // Shift-left s bits
while (t4 in [0, p.. 2^k-1]):    // If out of range...
      t4:= t4 << s               // ...repeat if necessary
psdn := t4                       // This is the pseudonym
```

Figure 1. Pseudocode of the algorithm

The difficulty to find the discrete logarithm *i* of the equation $a^i \bmod p$ is based on the assumption that *i* is randomly distributed and that no information can be used to reduce the number of possible values. This may not be the case if the persons ID is used as exponent *i*.

Two examples might help to demonstrate the problem. In both cases, *i* equals the person ID *id*. In the first example the exponent *i* is a continuous number starting with 1, so the n^{th} pseudonym belongs to the person ID *n*. If an attacker is able to estimate the number of already pseudonymized persons, the number of potential *i* is heavily reduced. In the second case, the person ID is created out of the birthday and a running number (e.g. 19850323012 for the 12th person born in March 23 of 1985). Knowing that a person was born at a certain day, also limits the number of potential *i* (in the given example to 100).

To avoid the reduction of potential *i* with prior knowledge about the person ID *id*, two processing-steps are performed, including one non-linear step:

1. XOR:
   The person ID will be XORed with a constant $c \neq 0$ of *k* bits
2. EXPAND:
   The intermediate result is multiplied with an expansion factor *q* mod *p*, $(1<q<p)$

Step 1 might lead to an invalid results that is out of the range of the allowed values ($0, p..2^k-1$). If this happens the XOR must be reversed. In case of *p* be close to 2^k, the number of invalid values ($p..\ 2^k-1$) can be minimized, which lowers the risk to revers the XOR step.

p being prime guarantees that the result of step 2 is still in the range of *1..p-1*, avoiding any doubles.

At that point, even with pre-knowledge about the person ID, no conclusions about the exponent *i* of the calculation $a^i \bmod p$ can be made, which would allow to reduce the search space. Finally, the main calculation step $a^i \bmod p$ can be performed.

Unfortunately, if the prime number *p* is small, it is possible to calculate all possible $b=a^i \bmod p$ to set up a solution table $b \mapsto i$. For a prime smaller than 2^{31}, maximal 8GiB are needed to setup such a table (1GiB = 2^{30} Byte). Even for prime smaller than 2^{40}, a solution table with maximal 5TiB needs to be pre-calculated (1TiB = 2^{40} Byte). Tables with that size fit in currently used RAM or hard disks and are no burden for potential attackers. A solution to

```
t1   = id XOR c
     = 300568 XOR 1656294509 =
     = 1656593013

t2   = (t1 · q) mod p
     = (1656593013 · 41795) mod 2147483647
     = 284715408

b    = a^t2 mod p
     = 572574047^284715408 mod 2147483647
     = 465777933

t3   = b XOR d
     = 465777933 XOR 913413943
     = 766681658

t4   = t3 <<_s
     = 766681658 <<_11
     = 353489627

psdn = t4
     = 353489627
```

Figure 2. Example calculation

overcome this problem is to also keep the primitive root *a* secret. In that case, with given *b* and *p*, for each *a* a different *i* exists that fulfills the equation.

The entropy of the secrets a, *q* and *c* that have been used so far might be insufficient to avoid brute force attacks. So a final round of confusion is performed:

3. XOR:
   The intermediate result will be XORed with a constant *d≠0* of *k* bits
4. LEFTSHIFT:
   The intermediate result will be shifted *s* bits left (|s|>0)

As with step 1, step 3 must be reversed, if the result is invalid. If the intermediate result of step 4 leads to an invalid value, it must be repeated until the intermediate result is in the allowed range. Both strategies do never introduce duplicates.

The calculated pseudonym *psdn* finally is the outcome of step 4. Fig. 1 on the previous page lists the entire algorithm as pseudo code.

The complexity of an attacker to re-identify the person ID is based on the secrets *a*, *c*, *d*, *q* and *s* and requires knowledge about some person ID / pseudonym pairs to proof if the secrets are correctly identified.

E. Example

Let *k=31* and prime $p=2^{31}-1=2147483647$.
a=572574047 is a primitive root from *p*.
The initial value will be XORed with *c=1656294509*.
The intermediate result will be XORed with *d=913413943*.
The expansion factor is defined as *q=41795*.
Finally, an intermediate result will be shifted left with *s=11* bits.
All calculation steps of the pseudonym for the identifier *id=300568* are the shown in Fig. 2.
The pseudonym that has been calculated from this identifier is *353489627*.

F. Finding a primitive root

For a given prime number *p* it is unnecessary to find all primitive roots to select the secret *a*; only one primitive root is needed. The density of primitive roots is quite high so it requires approximately four random tries in case of $p=2^{31}-1$ until a primitive root is found. To proof if a selected *a* is a primitive root, the series of $a^i \bmod p$ *(i=1..p-1)* has to be checked. If $a^i \bmod p = 1$ *with i≠p-1*, the series can be stopped and *a* is not a primitive root. In that case we found two exponents resulting in the same value: $a^{i+1} \bmod p = a = a^1 \bmod p$.

The series can easily be calculated with

$$a^0 \bmod p = 1 \tag{4}$$

$$a^i \bmod p = a(a^{i-1} \bmod p) \bmod p \text{ for } i=1..p-1 \tag{5}$$

G. Calculating $a^i \bmod p$

For the calculation of $a^i \bmod p$ in the described pseudonymisation algorithm, the pre-calculation of $a^{i-1} \bmod p$ is not available; so, the recursion as mention in the previous sub-chapter is inapplicable. Alternatively the calculation can be quickened if *i* is split into its binary representation:

$$i = \sum_{j=0}^{k-1} 2^j \cdot i_j \quad with\ i_j \in \{0,1\} \tag{6}$$

Then

$$a^i \bmod p = \tag{7}$$

$$a^{\sum_{j=0}^{k-1} 2^j \cdot i_j} \bmod p = \tag{8}$$

$$\left(\prod_{j=0}^{k-1} a^{2^j \cdot i_j} \right) \bmod p \tag{9}$$

This calculation is very fast in case of pre-calculated $a^{2^j} \bmod p$ using

$$a^{2^0} \bmod p = a \tag{10}$$

$$a^{2^j} \bmod p = (a^{2^{j-1}} \bmod p)^2 \bmod p \quad \text{for } j=1..k-1. \tag{11}$$

III. RESULTS

The algorithm for the calculation of the pseudonym would be useless, if the used secrets allow a brute-force attack. This is not the case, if the entropy of the used secretes is big enough. Furthermore, the size of the pseudonym must allow a human-readable representation and the effort to calculate the pseudonym must allow the calculation of a high number of pseudonyms per time.

A. Bit-depth of the secrets

Several secrets to calculate the pseudonym are used:

- The random number *c* that was used to XOR the exponent
- The factor *q* that was used to expand the exponent
- The primitive root *a*
- The random number *d* that was used to XOR the intermediate result
- The number of left-shifts of the intermediate result *s*

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TABLE I. FACTS

	4-byte signed integer	5-char base64 6-char base32	2-byte signed short integer
Bits	32	30	16
maximal positive value	2^{31}-1	2^{30}-1	2^{15}-1
highest possible prime	2^{31}-1	2^{30}-35	2^{15}-19
highest possible person ID	2 147 483 646	1 073 741 789	32 748
number of invalid values	2	36	20
number of possible primitive roots of the prime	534 600 000	459 950 400	10 912

The number of possible primitive roots can be calculated with Eulers φ-function and is $\varphi(\varphi(p)) = \varphi(p-1)$.

As an example, let us calculate the bit-depth of the secrets in case of data types that are usually used to store person IDs:

- 4-Byte signed integer:
  The number space is sufficient for a third of the entire living population on earth or four times the number of the living population of the European Union.
- 2-byte signed short integer
  The number space is only useful for a small set of persons, e.g., for persons of a clinical study.
- 5 chars of base64-encoded numbers or 6 chars of base32-encoded numbers
  (in case of efficient human readability)
  The number space is sufficient for two times of the living population of the European Union but insufficient for the living population the People's Republic of China.

With the information of Table I, we can calculate the entropy of the secrets that are used during the calculation (Table II).

For integer and the encoded char-values, the secret with entropy of ≈124 bits is sufficient to avoid effective brute force attacks. This is void for short integer. Here the entropy of the secrets is only ≈64 bits. In that case, the calculation of the pseudonym must be performed in two rounds with different primitive root, expansion factor, XOR and shift values. This does not fully double the entropy of the secrets because the final steps XOR and SHIFTLEFT are directly followed by another XOR step of the next round. All three steps can be simplified to only one XOR plus SHIFTLEFT. However, the entropy of the secret (≈111 bits) is sufficient today.

B. Human readability and usability

Without going into details, the readability of a pseudonym depends on the used character set plus the number of chars. Usually eight chars grouped in four chars is the maximum that a user in a day-to-day base accepts if the pseudonym has to be read and manually typed into a system. To represent the living population of the People's Republic of China at least 31 bits are needed that have to be encoded in the maximal eight chars. This allows either to use reduced character set (base32 instead of base64) or to introduce chars that are used for error correction or error detection. If a smaller population needs to be pseudonymized, the Faldum code [3] could be used. This code is able to encode 2^{30} persons in eight chars, including two chars for error detection.

TABLE II. ENTROPY OF THE SECRET

Secret	4-byte signed integer	5-char base64 6-char base32	2-byte signed short integer
q: primitive roots	≈ 29 bit	≈ 29 bit	≈ 13 bit
q: expansion factor	≈ 31 bit	≈ 30 bit	≈ 16 bit
c: XOR exponent	31 bit	30 bit	15 bit
d: XOR result	31 bit	30 bit	15 bit
s: shift result	≈ 5 bit	≈ 5 bit	≈ 4 bit
total	*≈127 bit*	*≈ 124 bit*	*≈ 63 bit*

C. Calculation speed

There are only a few steps involved in the calculation of the pseudonym. The calculation of $a^i \bmod p$ is identified as the most time consuming calculation. The calculation is straightforward and avoids several rounds until the final result is available. Multiplications are always more time consuming than XOR or shift operations so it is assumed that the pseudonym calculation is slower that the competitive approaches. In the known scenarios, the number of pseudonymisation calculations per time is sufficient: Tests have shown that on average hardware (Intel Core 2 Duo, 2.66 GHz) 132.5-thousand pseudonyms per second can be calculated.

IV. DISCUSSION

Important for the evaluation of the algorithm is the resistance against attacks and the possibility for re-identification.

A. Attacks

It is known that for $b = a^i \bmod p$ (p prime, a primitive root of p) it is difficult to calculate the discrete logarithm i, if b, a, and p are known and p being big enough to avoid solution tables. In our case, also the primitive root a is unknown. On the other hand, there might be pre-knowledge about i. With the non-linear diffusion steps that base on the use of non-trivial secrets (e.g. $q \neq 1$, $c \neq 0$), the exponent is complex enough to make the information of the initial series useless.

Brute force attacks will only be possible if an attacker is able to validate the set of parameters with a given set of person IDs and their associated pseudonyms. An attacker will in worst case only get both sets, not knowing which person ID and pseudonym is finally linked. Depending on the size of the set it is likely, that several parameter sets lead to the same transformation of the set of person IDs to the set of pseudonyms. In case of leaked pairs of person ID plus pseudonym, this information can only be used to perform a brute force attack. A recalculation of the used parameters is not possible.

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B. Re-Identification

A fast re-calculation of the person identifier is possible if all secrets are known. In case of small p and a given a, the solution table for $b=a^i \bmod p$ is made fast and every step of the entire calculation process can be reversed.

Only if the solution table cannot be pre-calculated, it is quicker to pseudonymise all known person IDs again to find the correct person ID.

C. Applicability

The concept of pseudonym-creation was implemented in a real-life scenario; in a research institute, a database with data collected for long-term studies, had to be split up into two versions: One version contains all the medical data plus the demographics of the patient as usual. The second pseudonymized version contains study specific extracts of study related data only.

To simplify the migration and to avoid an adaption of the used tools, the data-model in the pseudonymized version was kept unchanged. As a consequence, the pseudonym had to be in the same number range as the initial person ID. In our case both are integer with 2^{31}-1 as the highest possible value. Additionally, the person IDs is a consecutive running number, starting with 1.

The algorithm that was described in the paper is now used to calculate study specific pseudonyms. For each study, a different set of secrets is used as the calculation parameters. A tool was also provided to identify primitive roots.

V. CONCLUSION

The described algorithm for the creation provides a collision free one-way pseudonymisation technique for a small bit-depth of the person identifiers that allows a further use to create human readable and usable pseudonym. In contrast to other solutions, the algorithm is based on a hard problem and therefore is resistant against cryptoanalyis.

In case of more bits that are used of the person identifier, the identification of primitive roots will become more time consuming. The current strategy can only be optimized to a certain extent. It might be interesting for the future to identify the limit. But on the other hand, a pre-calculated fixed primitive root could be used for higher bit-depth, if a pre-calculation and storage of $a^i \bmod p$ is not possible. In that case one could use cloud services to find the fixed primitive root.

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If They Designed It, Why Don't They Want It?

The Lack of Acceptance of an ehealth Data Records System

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Abstract—**Although the design of an ehealth data records system was largely driven by carers themselves, ultimately these same carers did not want to use the system once a series of pilot studies ended. The reasons for this lack of acceptance of the system by carers at seven different care organizations in the United States, the United Kingdom and the Netherlands are explored. Four reasons are put forward to explain this lack of acceptance: 1) the ability of the system to be used to evaluate job performance; 2) the pilot study model; 3) reluctance on the part of the carers to alter work routine; and 4) the system's introduction is premature.**

Keywords—ehealth data records systems; mobile devices; acceptance of innovative technologies

I. INTRODUCTION

The adoption of ehealth records systems has been much slower in the United States than anticipated as well as in most European countries. This is the case even though the United States "government set aside $27 billion for an incentive program that encourages hospitals and providers to adopt electronic records systems" [1]. Although there is some debate over the reliability of ehealth records systems [2], there appears to be little doubt that the greater the ease of storage, access and cost savings will eventually achieve close to universal usage within institutions and among physicians [3, 4]. If the pace of adoption in hospitals and physician practices has been slow, the pace of adoption of ehealth data systems for use to chronicle care and services in the home has been even slower. There is little debate that the delivery of care and services in the home has increased significantly and will accelerate at an ever more rapid pace over the coming several decades because of two basic factors: demography and cost. The demographic trends are well known: dramatic increase in the number of elderly, especially the oldest-old; a concomitant increase in chronic diseases associated with aging; and a decline in the number of informal carers who can provide care. Cost projections are similarly daunting: increasing cost for care delivery within the institutional setting; insufficient number of institutions and insufficient funds to build the large number of additional institutions; and prohibitive costs to government to provide care and services through current care delivery models.

It is generally agreed that the only way to meet the increasing needs brought about by the demographic trends, while at the same time not bankrupting national treasuries, is to provide more care and services in the home [5]. As more care and services are being delivered in the home, several issues have emerged that raise serious concerns. In the first place, the care being delivered had steadily become more extensive. Whereas a decade ago rehabilitation after a serious illness or accident would have been undertaken in a specialized facility, presently many of these services are being provided in the home on an outpatient basis. But rehabilitation is just one of an escalating number of care services being provided in the home: nutritional counseling; wound care; psychological therapy; and medication adherence, to name several of the major ones. Additionally, the range of products and non-care services supplied to individuals in their own homes has increased significantly: oxygen; specialized beds; monitoring; meals; housekeeping; shopping; companion services. As the care and services have multiplied, so have the number of people providing the services. These companies/agencies are, of course, in addition to any services provided by informal carers. Thus, the need for a means of recording and tracking the care and services provided in the home are essentially the same as for institutions: increased reliability; better coordination; appropriate level of care; and cost savings.

As more care and services are delivered by more people representing different companies and agencies, just keeping track of who is providing what becomes increasingly difficult, especially if the individual receiving the care lives alone in her home and is experiencing cognitive decline or other impairments. Scheduling of visits and deliveries, ensuring the correct product or service, avoiding duplication all become difficult if records are scattered among various agencies, companies and individuals and are rarely, if ever, shared. It is also extremely difficult to evaluate if the care and services are having the desired impact on the individual if there is no systematic way to track the outcomes of the care and services. The lack of systematic and comprehensive records also makes it difficult for other care providers to make informed care decisions, since the reliance on the patient to remember specifics about the care and services in the home has proven to be suspect at best. In addition, if ehealth records of care and services in the home do not exist, it is obvious that they cannot be linked with the records that have been created in the hospital and the physician practice. Finally, even though delivering care and services in the home is more economical than in institutions, it still costs money and someone has to

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pay for it. As a result, from the point of view of the client receiving the care and services, as well as the insurance company and the government, there is a discernible need to track the care and services to ensure that what is paid for is provided and that everyone was paid appropriately.

This paper reports on the development of a wireless ehealth data records system: the Home Care Informatics System (HCIS) and the problems associated with acceptance and use of it. In the next section, the three stages of the development of the HCIS are outlined; in section three the reasons for the lack of acceptance on the part of the carers are analyzed; in section four a comparison is made with another electronic records system that has had similar difficulties with acceptance; and in the last section future scenarios for such records systems are explored.

II. THREE STAGES OF DEVELOPMENT

It is necessary to briefly explain the rationale for allowing the end-users (carers) to play a major role in the design process of this particular ehealth data records system. Results from a previous innovative ehealth project [6] had indicated that if end-users did not "buy-in", then the new technology would not be used. Thus, it was decided that in this project as much control, as possible, over the design of the system would be ceded to those individuals who were actually going to be using the system to aid in care delivery. This approach appeared to make sense at the time, but given that even after ceding control to the users, there was great reluctance on their part to employ the system, questions about the wisdom of this decision must be raised.

A. Stage 1—2006-2007

The first iteration of the system was created to systematically collect data generated in one of a series of pilot studies to test the effectiveness of a behavioral monitoring system [7, 8, 9]. This particular pilot study took place at Selfhelp Community Services, Inc. in Queens, New York and involved eleven geriatric social workers who provided care management services to over 200 residents. Twenty-seven of these clients agreed to have the system installed for a six month period and to have the social workers use the resultant data in care management decisions. The problem was that there was no way to systematically collect information on the care actions that they took in response to an alert. The instrument created was labeled the **TAO**: **Trigger**, the system's alert; **Action**, the care action taken by the social worker in response to the alert; and **Outcome**, the health or care outcome brought about by the care action. A brief example illustrates the initial design of the TAO:

> The system sends an alert to the geriatric social worker indicating an increase in overnight toileting for a particular client—the **Trigger**;
> The social worker phones the client to inquire about the client's behavior—the **Action**;
> Finding out that the client was frequently in the bathroom because of a stomach flu, the social worker contacts the client's physician to obtain a prescription for medication—the health **Outcome**.

At first, the social workers filled out a paper form with the relevant information, which was then entered into a computer data base. The carers viewed the paper version of the TAO as time-consuming to fill out and redundant with other forms. In response to these criticisms, a computerized web-based version of the TAO was created and this new version became the first design change driven by its users.

The Web-TAO form took about five minutes to fill out, could be easily shared with others and, most importantly, could be updated as more actions and outcomes occurred. In the short run, this last feature proved beneficial for the social workers as they could quickly and almost effortlessly update the Web-TAO records for individual clients. In the long run, the need to have an update capability proved essential in the development of the HCIS. This is because, although the alert is a discrete event, care actions and health outcomes are not discrete, but instead roll out over time. The previous example of the TAO narrative has all three elements as discrete events—one Trigger, one Action, one Outcome—and this example corresponds to approximately 40% of the TAOs. However, a majority of the TAOs corresponded more to the following example:

> The system sends an alert to the geriatric social worker indicating an increase in overnight toileting for a particular client—the **Trigger**;
> The social worker phones the client to inquire about the client's behavior—the **Action**;
> Finding out that the client was frequently in the bathroom because of a stomach flu, the social worker contacts the client's physician to obtain a prescription for medication—the health **Outcome**;
> The social worker phones the client's daughter to report that her mother has the flu—**Second Action**;
> Daughter visits her mother the next day finding out that her mother is no better—**Third Action;**
> Daughter phones social worker reporting on mother's condition—**Fourth Action**;
> Social worker visits client, determines that she is dehydrated, phones physician—**Fifth Action**;
> Physician decides to have client admitted to hospital—**Sixth Action, Second Outcome**;
> Client is discharged after two days in hospital—**Seventh Action, Third Outcome.**

All of the above actions and outcomes were the result of the single alert and could now be entered into the Web TAO as the events rolled out in real time. As a record of care provided and outcomes generated, the Web-TAO proved extremely helpful to the geriatric social workers as they could more systematically track the progression of care and outcomes. However, the realization of how multiple care actions and

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outcomes could be gathered together in a single record proved invaluable for the future development of the informatics system that eventually became the HCIS.

Once this alteration was made, the carers had other suggestions: add auto-populated fields; use check-boxes whenever possible; allow for easier follow-up entries; and allow access to individual records by other social workers and supervisors. At the first care review meeting, after these changes were made, two issues that would drive much of the development of the TAO surfaced. Since the objective for these meetings was to review what had happened to each of the clients over the previous month in order to assess how the monitoring system had impacted the delivery of care, it was not surprising that the TAOs were the focus of the discussions but it was surprising how the social workers utilized the TAOs. They placed the TAOs for each of the clients together and then worked their way chronologically through the TAOs. By their actions, the social workers were constructing an on-going record for each of the clients by putting TAOs for the particular client together into a single "pile". This "piling up" was the first care record and would drive much of future development of the ehealth system.

The second issue raised by the geriatric social workers concerned the ability of the Web-TAO in the evaluation of performance. For the supervisors, the Web-TAO provided an objective basis on which to evaluate the work performed by the social workers; for the social workers, the Web-TAO allowed supervisors to question their actions and professional conduct using information that had not been available previously. These issues were not resolved before the study ended, but, as discussed subsequently, it remained a vexing problem for the future development of the ehealth system.

B. Stage 2—2007-2008

As the Selfhelp pilot was ending, the pilot in London began. Unlike the Selfhelp study in which all clients lived independently and had their care managed by a single care organization, the London study involved several residential types and more than one care organization. All residents lived in Southwark, an area of Central London south of the Thames, and were provided services from one of three care organizations—Southwark Falls, Oasis and Hyde Housing—all of which operated under the broad umbrella of the Southwark Local Authority. Thus, the work undertaken by "carers" in these organizations was much more coordinated than would be found in three independent organizations in the United States. However, even though these organizations were "independent" and served distinct populations, for this discussion it makes sense to view them as a single entity, the Southwark Study, and to aggregate their 97 clients.

Based on the development work undertaken at Selfhelp, the Southwark Study began with a fully operational Web-TAO that had the ability to easily update a report as care actions and outcomes rolled out over time. Within the first six weeks of the study, it became apparent from the analysis of the material being entered into the Web-TAO that the carers were using the system much differently than the social workers at Selfhelp. This was primarily due to the fact that the culture at Southwark was extremely collaborative and, although particular carers had primary responsibility for specific clients, all carers engaged with all clients in some fashion, and thus, the Web-TAO was conceived as a tool to allow for easier sharing of information among all carers rather than just a record of responses to triggering alerts. Therefore, the ability for all members of the care team to not only view the information, but to contribute to the information stream became paramount. The cultural imperative to share and contribute to the information of clients resulted in a modification that allowed for much longer narratives to be entered into the system which, as a result, took on the appearance of "blogs" in which numerous carers listed their actions and the subsequent outcomes for particular clients. Fig. 1 is an example of a typical "blog" for a single client.

Trigger	-Wake up
Actions	-Phoned client -Visited client -Spoke to care professional Care Coordinator, GP -Contacted other person Spoke to OASIS Support Worker -Other action taken: Support worker spoke to client face to face, spoke to the surgery concerning the medical health of the client, GP to call back.
Outcomes	10/25 10:04) Client has been complaining of hip pain for the last two days but on prompting to attend GP surgery or to have home visit, she declined. When support worker visited, she found out that the client appeared unwell and movement was very slow.. Client had not eaten since last night so Support Worker prompted nutrition and medication and asked the client's permission to call GP to look at her hip. Client has agreed and a call has been made to book for a GP to examine the client. GP is aware of the needs, we have left a telephone message on the Next of kin's mobile number and Care Coordinator has been informed. GP visited and assessed Mrs B yesterday. She prescribed paracetamol for pain relief as it was found out that the arthritis in her hip was causing her so much pain. Client is still not able to get out of bed earlier but we hope that the pain will subside. Plan: Monitor the effect and report to GP as the condition changes. Care Coordinator to note. (10/26 10:47) GP stated that Mrs B appeared confused when examined and advised her to increase her fluid intake and contact the Specialist Mental Health Care Coordinator to assess the situation. (10/30 11:42) Following GP's prescription for pain relief, QuietCare showed that Mrs B visited the bathroom at 4.53 am and got out of the bedroom at 9.59 am which was unusual from recent data. She has been on pain relief since Friday 26th October and there appears to be a marked improvement in her health.

Fig. 1. Web-TAO blog narrative

On the surface, this change appeared to be trivial, but in actuality it altered much of the design of the structure of the Web-TAO going forward. The Web-TAO had already mutated from a research tool to a care provision tool that tracked responses to the system's alerts, and now it had transformed again from a limited record of what transpired when an alert occurred, to a more comprehensive ehealth record of all care being delivered to a specific client over time. Fig. 1 not only shows the comprehensive nature of the information recorded, but also illustrates how many carers became involved in contributing care for this client.

The members of the newly formed Smart Team had other suggestions for the Web-TAO. One was to be able to send the "blog" to a client's physician prior to an appointment in order

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for the physician to have all relevant care information. This required the creation of a new security function that limited who could send and what could be sent to individuals outside the Southwark Smart Team. A second suggestion was to allow the "blogs" to be sorted by alert, particular carer, type of care actions and date of entry. Although technically not a complex undertaking, the challenge was to understand the use to be made of such a sorting feature, before creating it. This change took time and the requested feature only became fully operational near the end of the study.

C. Stage 3—2008-2012

Work in the Netherlands began in late 2007 as part of a demonstration project to evaluate the role of behavioral monitoring in the delivery of care in both a residential and institutional setting [10]. During the first stage (2007-2008) of the project the behavioral monitoring system was installed in the residences of 12 individuals living independently and 13 individuals living within a sheltered housing facility, while in the second stage (2008-2012) the system was installed in the residences of an additional 230 individuals living independently throughout the largely rural Limburg Region served by two care organizations. Similarly to how the three London organizations were combined, it makes sense to view these two organizations, as well as the demonstration project and larger study, as a single entity and to aggregate the 255 clients into a single Dutch Study.

Since the demonstration project in the Netherlands began as the London Study was winding down, it was possible to provide the Dutch with an enhanced Web-TAO which had the ability to produce "blogs", which we renamed the "Client's Journal". Of course, the content of the Web-TAO, e.g., check-boxes, auto-populated fields, instructions, had to be translated into Dutch. The care delivery model at the two care organizations—Proteion and Zorgroep—required that their care workers spend a considerable amount of each day traveling to and from clients' residences. Thus, they spent little time at the two organizations' administrative headquarters, limiting their ability to both access the Web-TAO and to enter information on computers. This problem was solved by developing the capability for the Web-TAO, renamed the Home Care Informatics System (HCIS), to be accessed on any smart mobile device. This change in the structure of the HCIS to a wireless mobile service raised several design challenges. First, everything had to be reformatted so that it could fit the small screen of the mobile devices. This led to an even greater reliance on check boxes and auto-populated features and to the development of more efficient scrolling features. Second, there was the challenge of making the HCIS display properly on the different smart devices used by the care workers.

Working directly with the carers during the demonstration project allowed for a series of other suggestions to be incorporated into the HCIS: 1) the Client's Journal feature allowed entries by any authorized personnel; 2) the Journal could be sorted by alert, date, care worker, type of care delivered and outcome; 3) there was a new feature that allowed additions to a previous entry, but not the elimination of the original entry; 4) a series of pop-up prompts helped the user navigate through functions and avoid common errors; 5) additional security features were developed to ensure that only authorized individuals could access and contribute to a client's record; and 6) a read-only feature was added. Even with these modifications, two issues remained unresolved. The first issue concerned how the HCIS was used during care review meetings at which time the care delivered to specific clients was discussed and decisions on future care made. These meetings included both individuals who had knowledge of and access to the HCIS and others who had neither. Since the client reviews were more thorough when everyone at the meeting had access to the information stored in the HCIS record, the question arose as to who should have access, how should they obtain access and who was in charge of making access happen? Although this issue does not directly concern the technical development of the HCIS, it certainly impacts the implementation of the HCIS and its long term use. The second issue concerned whether the information stored in the HCIS could be used by supervisors and administrators in the evaluation of work performance. On the surface, the concern expressed by the care workers in the Netherlands was similar to those raised by the social workers at Selfhelp. It was believed that these concerns could be fairly easily resolved by discussions of interested parties. This was not the case, and this issue remained unresolved at the end of the pilot.

D. Summary of Changes

Below is a summary of the changes made to the HCIS in response to the expressed needs of the people using it. A review of these changes brings into focus how much the TAO/HCIS changed during the six years studies in response to the wishes of the users.

Selfhelp

1. The TAO was put on the web;
2. A feature that allowed the sharing of TAOs was created;
3. Check-boxes were added;
4. Auto-populated fields were added;
5. A feature that allowed the follow-up entries was developed.

Southwark

1. Changes made to conform to British English;
2. Enhanced sharing capabilities developed;
3. Security features added to allow sharing of data beyond the Smart Team;
4. A blog structure was created that allowed data to be entered by multiple carers;
5. A feature that allowed the sorting of the blogs by alert, carer, care action taken, health outcome and date.

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The Netherlands

1. It was translated into Dutch;
2. The blogs became the Clients' Journals;
3. The system was made to be operational on any mobile device;
4. A feature that allowed additional carers to enter data was developed;
5. More auto-populated fields and check boxes were added;
6. A feature that allowed entries to be corrected without erasing the original was developed;
7. Additional search features were added to the system;
8. A read-only feature was created.

III. LACK OF ACCEPTANCE

The most frustrating aspect of the seven pilot studies was that even though the vast majority of the modifications made to the ehealth data system were in direct response to the expressed desires of the carers, ultimately they did not use the system. Although perplexing, this result does provide a vivid lesson for anyone trying to introduce a "new technology" into an existing work culture. In order to assess the reasons for this lack of acceptance, questionnaires were administered to all eleven social workers at Selfhelp, while individual carers were interviewed in the Southwark and Dutch studies. In London, 70% of the carers were interviewed by phone and in the Netherlands approximately a third of the carers were interviewed in person. Findings from the questionnaires and interviews indicated that there were three reasons for the lack of acceptance: 1) fear on the part of the carers that the information would be used to evaluate work performance; 2) the nature of the pilot study model and its impact on the carers' commitment; and 3) unwillingness of the carers to change their work routine.

A. Evaluation of Performance

Analysis of the carers' answers from the seven locations showed that the carers in the United States and the Netherlands were fearful that the information contained in the HCIS would be used by supervisors to evaluate their job performance. Two brief examples illustrate this ability of the information contained in the HCIS to evaluate the carers' performance. Each alert generated by the monitoring system is time stamped, as is every care action taken by a specific carer, and as a consequence, there is a concrete record of whether the carer responded to the alert and how long it took the carer to respond. In addition, the HCIS contains specific information on the type of response and the health outcome for each client over time, allowing supervisors to compare the work of different carers. It is this ability to compare the work of different carers which appeared to disturb the carers the most. And, it is indisputable that the HCIS allows this type of comparison to be made and for performance reviews to be based upon the information contained in the system. Not surprisingly, supervisors viewed this ability as an advantage because it documents performance, whereas, carers viewed it as an intrusion into their professional decision making.

B. Problems with the Pilot Study Model

The deficiencies of the pilot study model employed in the testing of the behavioral monitoring system have been detailed elsewhere [6], but some of these issues relate directly to the lack of acceptance of the HCIS. There appear to be four problems with the pilot study model. First, only a small number of carers were involved in the pilots at each of the organizations resulting in the studies being marginalized. At Selfhelp, only eleven of almost 200 social workers were involved in the study; while in London fewer than a dozen carers within the entire Southwark Local Authority had any role in the study and in the Netherlands, fewer than 5% of carers at the two organizations were involved in the study. Second, in no case was the HCIS used by the carer for all of her clients; instead it was always used for a small fraction of clients—on average no more than 20% and in only two cases over 50%—meaning that the carer was employing two different systems to record care. Third, information derived from the questionnaires and interviews showed that, because the carers knew when the pilot was to end, many carers put little effort into using the HCIS because they knew when it would go away. Finally, the HCIS was never part of "normal" care, but was always viewed as something that was just being "tested". As a result, the majority of carers responded logically by putting less and less effort into its use as the pilot progressed.

C. Unwillingness to Change Routine

Even though information from the questionnaires and interviews showed the importance of the previous two factors in the lack of acceptance of the HCIS by the carers, an even more important reason was their unwillingness to change their normal routine that did the most damage. There is no doubt that the HCIS required carers, at least initially, to do more work and undertake tasks which were unfamiliar. For example, in the Netherlands, carers, instead of just writing a couple of lines on a piece of paper kept in the client's residence were expected to type in information on their smart phones before driving to their next appointment. They were also expected to update this information as additional care was delivered and even track and record health outcomes over time. These tasks were viewed as especially egregious since not all of their clients were in the pilot study and, therefore, they had to employ two different recording systems. Finally, it was difficult for the carers to see the value in this extra effort, because the benefits of better and more coordinated care were in the future, whereas the extra work had to be done every day.

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D. Summary

Yet even with the problems outlined above, initially, in each of the care organizations, carers entered usable, and in some cases extraordinary, information on the care actions undertaken and the resultant health outcomes. This was especially true for the London studies, but it also occurred, albeit in a minority of cases, in New York and the Netherlands. The problem was that within four months the information the carers, at each of the organizations, were entering was increasingly uninformative and by the end of the pilots a majority of the carers had stopped using the HCIS altogether. This experience, although frustrating, does provide some guidance to anyone trying to introduce a "new technology" into an existing organization.

IV. DISCUSSION

The last of the pilot studies ended December 31, 2012 and currently the HCIS is not being used within any care organization. Thus, it would be fair to conclude that the HCIS is a failure, even though the HCIS is very clever and its design was driven by the desires and stated needs of its users. If it is not being used, there must be something fundamentally wrong with the concept and its implementation. However, there is one mediating factor that may require reevaluating the conclusion that the HCIS is a failure: the HCIS is not the only such system that has encountered problems of acceptance.

There has been a second wireless, ehealth records system that was developed and tested in Germany [11]. Even more interesting than the fact that two researchers independently developed such a system is that the problems of acceptance on the part of the users in the German study are parallel. The first problem that the carers had with the system was its GPS feature, which tracked their every movement. Thus, if a carer stopped on the way to a client to pick up her dry cleaning, her supervisor would know it. Additionally, with the GPS in place, supervisors could determine how long a carer spent in the residence of a client and could compare productivity of different carers. Even after the GPS feature was turned off, carers were concerned about the ability of the system to monitor their actions.

Also similar to the problems that were encountered in the seven pilot studies, the carers in the German study complained about the amount of time it took to type data into their wireless device. Responding to these complaints, the German researchers enabled a feature that allowed information to be entered by voice. Although this change was a direct response to the desires of the carers, the carers were still unhappy with the time it took to enter data and the need to check the accuracy of the information once entered. Finally, similar to my experience there were problems with the sharing of information among the various carers and the use of the information in the provision of care. Once again, there was a disconnect between the work of the carers and the benefits to their clients.

Two studies, however independent in conception and parallel in findings, do not necessarily contradict the conclusion that the HCIS is a failure, but it does suggest though, that it is necessary to rethink why the lack of acceptance occurred in such varied locations and what this means to the future of this type of wireless ehealth data system. It does not appear unreasonable to conclude that the main reason for the lack of acceptance is that developers, have underestimated the reluctance on the part of carers and their supervisors to change the way they do their jobs. In other words, it is a cultural and not a technological issue.

V. CONCLUSION

Two main findings are apparent from the material presented above: 1) it is possible to create an ehealth data system for home care and that such a system can be used effectively to coordinate care and services and contribute to the maintenance of independent living; and 2) the success of such a system is dependent on issues that do not concern design and functionality, but instead on its acceptability by the people employing the system. Even when much of the system's design was driven by these users, there was a lack of acceptance on the part of these very same people. Three reasons were put forward as the main factors for this lack of acceptance: the potential use of information in the system for the evaluation of job performance; the pilot study model; and the unwillingness of the carers to alter their normal routine. However, there may be an even more fundamental reason for the lack of acceptance of this particular wireless home care records system: its introduction is premature.

Many business experts have argued that new ehealth technologies, such as the HCIS, will not be widely adopted until the traditional care models can no longer meet the needs of the burgeoning elderly population [12]. Then, and only then, will administrators at care organizations be forced to introduce new technologies and compel their workers to use new systems. Until this point is reached, care will continue to be provided in the usual way, even as it becomes more difficult to achieve the goal of providing cost effective and timely care. The behavior of the Dutch carers speaks directly to this argument. Even with the HCIS readily available on their mobile devices, they preferred to write down their actions on pieces of paper that remained in the client's residence, even though the paper record could not be easily shared, updated or used in care reviews. Why? Because there was no compelling need and administrators deferred rather than forced them to use the new technology. Adequate care could be delivered without the use of the new system, so why change what one normally did, especially if it was only part of a pilot study that was going to go away in a few months anyway?

The slow pace of the adoption of electronic medical records in hospitals and physician practices provides a valuable lesson to those of us who are championing the use of ehealth systems. The United States government has encouraged the use of electronic medical records and even mandated their use wherever possible. Insurance companies have wholeheartedly endorsed the use of electronic records and have attempted to induce their use through economic

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incentives. Nevertheless, the pace of adoption has been slow as individuals complain about the cost in time and money. What is largely left unsaid is that, even with the incentives, given a choice, most administrators would not adopt the systems because currently there is no compelling need to adopt them. Are they more efficient? Probably. Is it worth the cost? Probably not. Is it worth the cost given the increasing expense and growth of the health care system that will stretch the system to the breaking point? Absolutely. But, this requires change today in anticipation of a future need and this is difficult for people to accept, especially when it disrupts their daily routine. This same set of questions can be applied to the HCIS and other ehealth data systems and the endpoint is, not surprisingly, the same: a demonstrative future need that requires change before people are ready to compel such a change. When will the dynamics change, two years from now, five years from now, a decade from now? It is not possible to predict with any certainty the exact date, but there will be a time when electronic record systems similar to the HCIS are part of the normal care model and people will wonder why they weren't in use earlier.

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Security Analysis and Performance Evaluation of the Linkable Access Protocol of the Electronic Patient Records

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***Abstract*—Information security and privacy in the e-health domain is an issue of growing concern. The adoption of electronic patient records, increased regulation, provider collaboration and the increased need for a faster information exchange between patients, providers and payers, all point to the need for a better information security. Therefore, the aim of this paper is to provide secure access to electronic patient records without compromising performance. To achieve this, we have designed a secure protocol called the Linkable Access protocol. In this paper, (1) we formally verify and analyse the Linkble Access protocol against security properties (e.g., confidentiality) using the Casper/FDR2 verification tool. In addition, (2) we build a prototype using the Java technology to demonstrate the performance of the Linkable Access protocol. By doing this, we prove that the Linkable Access protocol maintains a good balance between security and performance.**

Keywords-e-Health; electronic patient records; privacy; security; performance.

I. INTRODUCTION

Privacy is considered as a key governing principle of the patient-physician relationship. Patients are required to share information with their physicians to enable correct diagnosis and treatment, and to elude adverse drug interactions. Nevertheless, patients may refuse to disclose necessary information in cases of sensitive medical problems such as psychiatric behaviour and Human Immunodeficiency Virus (HIV), as their disclosure may lead to social stigma and discrimination [1]. Over time, Electronic Patient Records (EPRs) accumulate important personal information, including identification, history of medical diagnosis, treatments, medication history, dietary habits, sexual preference, genetic information, psychological profiles, employment history, income and physicians subjective assessments of personality and mental state [2].

EPRs offer a wide range of purposes apart from diagnosis and treatment provision. For example, information could be used to improve efficiency within the healthcare system, drive public policy development and administration, and in the conduct of medical research [3]. EPRs can also be shared with payer organisations (e.g., private insurance) to justify payment of services rendered. Health Service Providers (HSPs) also make use of records to manage their operations and improve service quality.

While the above mentioned technology can help improve overall quality of health care delivery, the benefits from this technology must be balanced with the privacy and security concerns of the patient.

In real-life situations, there are various scenarios, where authorized users have legitimate reasons to access patients' EPRs (which could be stored in a single or in multiple locations). Based on the principle of least privilege, users should only be granted with access rights that are just sufficient for them to carry out the tasks assigned to them.

The minimum level of access privilege is to only allow users to access de-identified records. De-identification means that patients' identifiable information is removed from the records [4]. There are three de-identification methods, anonymization, depersonalization and pseudonymization. Anonymization is the process of hiding (or removing) a patient's identification data and only make other information (i.e., de-identified information) available for access [5]. Depersonalization is a process similar to anonymization, but it comprises the removal of as much identification information as necessary to protect patient identity [6]. Pseudonymization, on the other hand, is the process of adding an identifier (called a pseudonym) into a patient's de-identified record [7].

Yet, in practice, there are times when, for legitimate reasons, multiple de-identified records of the same patient may need to be linked (e.g., when we need to study the history of a patient's medical condition) or an anonymised record needs to be re-identified at a later date. In such cases, a patient's pseudonym should be mapped or reversed to the patient's identity and two or more pseudonyms of the same patient should be linkable and these should be done in a controlled manner.

There are two types of pseudonyms, namely, irreversible and reversible pseudonyms [8]. Irreversible pseudonyms are pseudonyms that cannot be reversed back to the patient's real identity. Reversible pseudonyms are pseudonyms that can be reversed back to the original identity (i.e., a patient can be re-identified from his/her reversible pseudonyms).

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Most pseudonym generation methods used in supporting privacy preserving EPR access [9][10][11] , focus on preserving patient anonymity. They use irreversible pseudonyms to index de-identified records. This type of pseudonyms only supports anonymous data access. Though the pseudonym generation methods in [8][12], have considered the linkability requirement, they do not support a secondary use of patient information. That is, they do not allow linking of multiple pseudonyms of the single patient without revealing the patient's identity. A notable method that has addressed this limitation is LIPA [13]. Yet, LIPA supports this linkablity requirement, but assuming that patient records managed by different HSPs are stored in a single repository. The solution does not support distributed data access. To the authors' best knowledge, the works that are most related to our work are Deng's method [14] and the PIPE method [15]. Both methods aim to securely integrate primary and secondary usage of distributed medical data without compromising the patient's identity privacy. We described an alternative method [16] with the aim of reducing access delays. In other words, our method proved to be more efficient than Deng's and PIPE methods.

In detail, to facilitate the minimum access right management, we have proposed a new method called 3LI2Pv2 method to support controlled access to EPRs with three levels of identity privacy reservations [16]. In this method, we have identified three distinctive user groups, each with a defined level of access. The first group of users (called L3 users) are only given rights to access anonymised data. They are not allowed to identify the patient (i.e., the identities of the owners of the data) nor link multiple EPR objects of the same patient. The second group of users (L2 users) are allowed to access and link multiple objects of the same patient, but are not allowed to link the objects to their owner's (i.e., the patient's) identity. In other words, users in this group are allowed to access the multiple objects of the single patient without being able to identify the patient. Finally, the third group of users (L1 users) are allowed to access patients' records as well as identify the owners of the records. In other words, we have three levels of patient identity privacy protection.

* *Level-1 (L1)- Linkable access:* At this level, multiple data objects of the same patient can be linked, and this set of objects can be linked to the patient's identity. L1 access should be limited to L1 users, i.e., users with linkable access privilege.

* *Level-2 (L2)- Linkable anonymous access:* At this level, multiple data objects of the same patient can be linked, but this set of objects cannot be linked to the patient's identity. L2 access should be limited to L1/L2 users, i.e., users with linkable anonymous access privilege.

* *Level-3 (L3)- Anonymous access:* At this level, multiple data objects of the same patient cannot be linked, nor the patient's identity be exposed. L3 access should be limited to L1/L2/L3 users, i.e., users with anonymous access privilege.

The 3LI2Pv2 method made use of cryptographic techniques to achieve its goals. We have informally analysed the 3LI2Pv2 method against some security requirements, and the result was positive. For future work, we suggested to include the design of the access protocol for the three levels. Therefore, in this paper, we introduce a secure and robust protocol for the Level-1 (Linkable access), called the Linkable Access (LA) protocol. This type of access protocol provides the highest level of access in terms of revealing sensitive patient information, and only user holding the right type of credentials can perform this type of access.

Generally, security protocols have been designed and verified using informal techniques. As a result, it is now well known that many security protocols, which were previously proposed have found to be vulnerable afterwards. For example, the Needham-Schroeder public key protocol [17] succeeded in the informal analysis, but failed in formal verification [18]. To address this problem, formal methods have been widely used to specify security protocols and verify security properties, such as confidentiality, authentication and non-repudiation, to guarantee correctness [19].

In this paper, the Casper/FDR2 verification tool [20][21], is used to verify the LA protocol. Casper/FDR2 has proven to be successful for modelling and verifying several security protocols; it has been used to verify authentication, secrecy, and other security properties [22][23]. Accordingly, we consider it also appropriate for the verification of the LA protocol. The Casper/FDR2 model checker is used to verify the security properties of the protocols. If the protocols do not satisfy the specified security properties, then the FDR2 checker shows a counterexample which represents the reason against vulnerability.

After completing the formal verification of the protocol using Casper/FDR2, we implement the protocol using the Java technology [24] to test it against performance. Java is selected because it supports a set of standard security primitives. Examples of these primitives include the hash functions SHA-256 [25] and MD-5 [26], the symmetric cryptographic algorithms AES [27] and 3DES [28] and the asymmetric cryptographic algorithms RSA [29] and DSA [30].

This paper is organized as follows; In Section 2, we introduce possible security threats. In Section 3, we describe, model and verify the LA protocol. Also, we set the goals that the LA protocol should meet. After that, we show the result of the verification. In Section 4, we present the implementation and performance analysis of the LA protocol. In Section 5, we conclude the paper and discuss future work.

II. Possible Security Threats

Access to EPRs is subject to different kinds of security threats. We will not consider here threats of environmental origin (e.g., fire, etc.) or accidental ones (e.g., user errors, software malfunction, etc.). The deliberate threats that we will consider are categorized into three groups.

A. Confidentiality threats.
B. Integrity threats.
C. Authentication threats (including non-repudiation).

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A. Confidentiality Threats

In this type of threat, an attacker may gain access to private information. The attack consists in eavesdropping the communication links, without interfering with the transmissions, or in inspecting data stored in the system. Man in the middle attack, replay attack, credential forgery/theft and impersonation are examples of this type of threat.

B. Integrity Threats

Here, an attacker may modify the information exchanged within an e-health service. The attack consists in interfering with the transmissions, so that the recipient receives data, which are different from those sent by the originator. Data tampering is an example of this type of threat.

C. Authentication Threats

In this kind of threat, an attacker may counterfeit false data and deceive the recipient into believing that they come from a different originator (which the recipient takes as the authentic originator). The attack consists in forging the part of the data where the originator is identified (usually in the identity credentials). Spoofing is an example of this type of attack. Repudiation is also a variant of this type of attacks that consists in denying authorship or the contents of data previously sent.

III. Formal Verification of The LA Protocol

In this section, firstly, we describe and model the LA security protocol with Casper/FDR2 verification tool. Secondly, we identify essential security requirements that the LA protocol should meet. Finally, we discuss the verification result of the protocol and analyse its security requirements.

A. The LA Protocol Description

The purpose of the LA protocol is to link multiple objects (under a single or multiple HSPs management) of the same patient, and to link these objects to the patient's real identity (e.g., NHS number). This type of access should be limited to users with the highest access privileges (i.e., L1 users such as general practices, GPs). In real-life scenarios, this protocol can be applied to a GP who wishes to proceed with a patient's treatment and needs to have access to the patient's real identity from his de-identified records. The GP will need to get this patient's data from the attribute authority (aa). This authority can retrieve the patient's real identity on behalf of the HSP. Assuming in A3 below, this authority is trusted by HSPs and clients (e.g., GPs). Assuming in A4, all the patient's records have been de-identified. In order to get the data, the GP needs to prove to aa that he has been granted the right credentials to perform such type of access. In other words, the GP needs to, firstly, show his identity credential to ensure that he is the person he claims to be. Secondly, he needs to show his access credential, which confirms that he is allowed to perform this type of access and learn the patient's real identity.

Until now, no research has been carried out to analyse the vulnerability of the LA protocol using a model checking tool. Table I shows the basic notation of the LA protocol. Fig 1 shows the message sequences of the LA protocol.

In the LA protocol, the communication channel is based on the Secure Socket Layer (SSL) protocol [31] to provide security for data transmission. SSL protocol uses a combination of public key and symmetric key ciphers to establish a secure communication channel between a server and a client. For protocol analysis using Casper/FDR2, we assume the following.

A1. The underlying cryptographic algorithms used in SSL's public key and symmetric key ciphers are secure.
A2. All parties unconditionally trust the certification authority and public keys signed by it. The certification authority certifies the public key for clients.
A3. All parties unconditionally trust the attribute authority who issues the attribute certificates for clients.
A4. Patients' records have already been de-identified. That is their identity or NHS number has been replaced with a pseudonym.

TABLE I
THE LA PROTOCOL NOTATION AND DESCRIPTION

Notation	Description
a	An identifier of an initiator/client
ca	An identifier of a certification authority
aa	An identifier of a attribute authority
nx	A random nonce of x
PKx	A public key of x
SKx	A secret Key of x
ts	A timestamp (an expiration time)
h	A hash function
msg	A message of data request
certa	A PK-certificate of client a generated by ca
attr-certa	An attribute certificate of client a generated by aa
veri1	An integrity verification of certa
ps3l1	An L3 pseudonym Type-I
sigaa	A signature of aa
integ1, integ2	Used in attr-certa integrity verification

In the LA protocol, ca is the certification authority who issues public-key (PK) certificates, and aa is the attribute authority who issues attribute certificates to legitimate users. a is the client or the initiator of the request.

The PK-certificate includes two parts, {a, Pk(a), 11, ts} and {h(a, Pk(a), 11, ts}{SK(ca)}. The first part, contains information about the client, such as, identity *a*, public key of *a* PK(a), group membership *l1* and timestamp *ts*. The second part, is the signature of the *ca*. Issuer *ca* signs subject *a*, public key of *a*, *PK(a)*, a group membership *l1* and timestamp *ts* using its own private key *SK(ca)*, which is only known to the *ca*. Since the certificate is encrypted with the private key of ca, any other user cannot spoof it. This provides confidence of the certificate's information to a participant. The certificate can only be decrypted by the public key of *ca*, which is known to legitimate users. To sum up, The design of PK-certificate ensures that no one can forge or modify a valid PK-certificate. It is important to mention that in this protocol description scenario, we have also included issuing the PK-certificate and attribute certificate to the client. In real-life

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scenarios, certificates are issued once (unless expired and need renewal) and usually at an earlier stage before submitting a request to access patient data.

The following describes the message sequence of the LA protocol depicted in Fig 1.

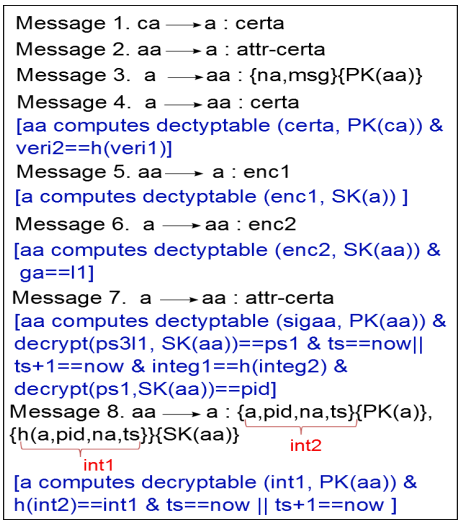

Fig. 1. The LA protocol description

Message 1: Certificate authority *ca* issues and sends the PK-certificate, *certa*, to client *a* in order to authenticate client a and distribute *PK(a)* safely.

Message 2: Attribute Authority *aa* issues and sends the attribute certificate, *attr-certa*, to client a. This certificate includes the issuer's name (aa), the client's name (a), an L3 pseudonym (ps3l1), a timestamp (ts) and the issuer's signature on the certificate. The L3 pseudonym (ps3l1), contains another pseudonym, a lower-level one called, ps1, which can be used to recover the patient's real identity.

Message 3: Client a sends his/her nonce (na) along with a message of the request encrypted with *aa*'s pubic key.

Message 4: Client a sends his PK-certificate (certa) to *aa*. This certificate contains *veri1* and *veri2*. *veri1* contains the plain content of the certificate. *veri2* contains the deciphered *ca*'s signature on the certificate. Using *veri1* and *veri2* allows checking the integrity of the certificate to ensure that the certificate has not been modified during transmission. So first, verifier *aa* validates the *ca's* signature on the certificate and then, it verifies the certificate's integrity using *veri1* and *veri2*.

Message 5: Verifier *aa* sends *enc1* to client a which contains the verifier's identity (aa), user's nonce (na) and the verifier's nonce (naa) encrypted with $PK(a)$. Client a checks if *enc1* is decryptable by $SK(a)$ and contains the right nonce na. This step is essential to allow client a to authenticate verfier *aa*.

Message 6: Now client a sends *encr2* to recipient *aa*. Variable *encr2* contains the items a and naa encrypted with $PK(aa)$. Recipient *aa* checks if *enc2* is decryptable by $SK(aa)$ and contains the right nonce naa. This step is essential to allow *aa* to authenticate a. Also in this step, *aa* checks a's group membership to ensure that the client belongs to the right group and legitimate for this type of access.

Message 7: After successful authentication, a sends to *aa* his *attr-cert* to check his authorisation. Verifier *aa* checks the correctness of the certificate. It completes this by verifying the signature on the certificate and checks a's access credentials. That is to ensure that the certificate contains the right type of L3 pseudonym (ps3l1). After that, it verifies the integrity of the lower-level pseudonym (ps1) to ensure it has not been altered during transmission.

Message 8: After successful authorisation, *aa* forwards *int1* and *int2* to a. Variable *int2* contains the requested patient's data (pid), a timestamp (ts), user's nonce (na) and the user's identity (a) all encrypted with the user' pubic key. Variable *int1* contains same items as in *int2* but hashed. Finally, user a performs the final checks. (1) Checking the aa' signature on *int1* and verifying the integrity of the data using *int1* and *int2*. (2) Checking the timestamp to ensure data freshness.

B. Modelling the LA protocol Using Casper/FDR2

Based on the LA protocol's notation in Table I, we model the LA protocol in Casper's script, as shown below.

```
#Protocol description
--ca issues and sends PK-certificate to client a
0. ca -> a : {{a,PK(a),{l1}%ga,ts}%veri1,{{h(a,PK(a),
{l1}%ga,ts)} %veri2}{SK(ca)%skca}%certa}{PK(a)}
--a wants to contact aa
1. -> a : aa
--a sends his original request message with a nonce
2a. a -> aa : {msg, na}{PK(aa)}
--a sends his PK-certificate to be verified by aa
2b. a -> aa :{veri1%{a,PK(a),ga%{l1},ts},{certa
%{veri2% {h(a,PK(a),ga%{l1},ts)}}} {SK(ca)}}{PK(aa)}
[decryptable(certa, PK(ca)) and veri2== h(veri1) and
ts==now or ts+1==now]
--Mutual authentication and check user membership
3. aa -> a : {aa, na, naa}{PK(a)} %enc1
[decryptable (enc1, SK(a))]
4. a -> aa :{a, naa}{PK(aa)} %enc2
[decryptable (enc2, SK(aa)) and ga==l1]
--aa issues and sends attribute certificate to a
5a. aa -> a :{aa,a,{{ps1,l1, aa, nonce}%integrity2,
{h(ps1, l1, aa, nonce)}% integrity1}%ps3l1,ts}{PK(a)}
5b. aa -> a : {h(aa,a,ps3l1,ts)} {SK(aa)} %sigaa
[ts==now or ts+1==now]
--a sends to aa his attribute certificate for
authorisation verification
6a. a -> aa :{aa,a, ps3l1 %{integrity2%{ps1,
l1,aa,nonce},integrity1%{h(ps1,l1,aa,nonce)}}, ts}
6b. a -> aa :sigaa%{h(aa,a,ps3l1,ts)}{skaa%SK(aa)}
[decryptable(sigaa,PK(aa)) and integrity1==
h(integrity2) and decrypt(ps3l1, SK(aa))== (ps1,
l1, aa, nonce) and decrypt(ps1, SK(aa))==pid and
ts==now or ts+1==now]
--aa sends the response to a
7. aa -> a : {{a, na, pid, ts} %int2,
{h(a,na,pid,ts)%int1}{SK(aa)}%sigaa2}{PK(a)}
[decryptable(sigaa2,PK(aa)) and int1== h(int2) and
ts==now or ts+1==now]
```

C. LA Protocol Goals

In this section, we identify the LA protocol security goals or properties.

(P1) Data Confidentiality: Confidentiality is a vital requirement that provides secrecy and privacy in e-health applications. It offers protection against attacks such as forgery and spoofing. To support data confidentiality, the communication

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channel between entities should be secured typically via encryption. An unauthorised party should not be able to learn anything about any communication between two entities by observing or even tampering the communication lines. That is, one cannot infer the contents of the message, sender and receiver, the message length, the time they were sent, and not even the fact that a message was sent in the first place.

(P2) Integrity Protection: A strong integrity protection mechanism should be deployed to protect against data tampering. The LA protocol should detect any unauthorised alteration to data being transmitted between the authorised entities.

(P3) Ensuring Accountability: The protocol should obtain an undeniable response from entities participating in the protocol. That is, to ensure that the originator of a communication cannot deny it later.

(P4) Mutual Authentication: Or two-way authentication, refers to both entities of the protocol should authenticate each other to permit the exchange of information there-between.

(P5) Certificate Manipulation Protection: It should be guaranteed that the certificates (i.e., PK-certificates) used in the protocol are valid and have not been corrupted or modified during transmission.

(P6) Credential Forgery Protection: It should be assured that users' credentials are not stolen or forged. This is because it can lead to the elevation of privileges attack. This attack occurs when a user with limited privileges assumes the identity of a user with higher privileges to gain access to patient confidential data.

(P7) Data Freshness: There should be a proof that nonces, generated during protocols, are fresh and the integrity of the session key is preserved. Both entities should also have undeniable proof that the other party is in possession of a valid session key. Any previous compromised key should be easily detected, and the protocol run should terminate.

(P8) Linkability: A user with L1 access credentials, i.e, highest access privileges, should be able to link de-identified or anonymous objects to the patient's real identity.

D. Verification Result and Security Analysis of The LA Protocol

The verification result using the Casper/FDR2 model checking tool confirms that the LA protocol has fulfilled all the properties identified in Section III-C. The result of the verification is shown in Fig 2.

(P1) Data Confidentiality: was achieved by deploying cryptographic techniques (symmetric cryptoystem, asymmetric cryptoystem, and hash functions).

(P2) Integrity Protection: was met by incorporating digital signatures and hash functions, which can detect any data alteration during transmission.

(P3) Ensuring Accountability: was fulfilled by using digital signatures of both entities, the sender and receiver.

(P4) Mutual Authentication: was accomplished by integrating the challenge response protocol.

(P5) Certificate Manipulation Protection: this property has been abided by including a timestamp in the certificate, which

```
Initialising Casper....  Done.
Initialising FDR....  Done.
Ready.

Casper version 2.0

Parsing...
Type checking...
Consistency checking...
Compiling...
Writing output...
Output written to /home/Rima/Download/casper-2.0/L1-Protocol.csp
Done

Starting FDR
Checking /home/Rima/Download/casper-2.0/L1-Protocol.csp

Checking assertion SECRET_M::SECRET_SPEC [T= SECRET_M::SYSTEM_S
No attack found

Checking assertion SECRET_M::SEQ_SECRET_SPEC [T= SECRET_M::SYSTEM_S_SEQ
No attack found

Checking assertion AUTH1_M::AuthenticateSERVERToINITIATORAgreement_na
[T= AUTH1_M::SYSTEM_1
No attack found

Checking assertion AUTH2_M::AuthenticateINITIATORToSERVERAgreement_naa
[T= AUTH2_M::SYSTEM_2
No attack found

Done
```

Fig. 2. Verification result of the LA protocol using Casper/FDR2

can detect any sniffing and manipulation by the intruder.

(P6) Credential Forgery Protection: was met by including the legitimate credential holder identity in both types of certificates, the PK-certificate and the attribute certificate. So by checking that both certificates contain the same credential holder identity, we can ensure that both credentials have not been forged.

(P7) Data Freshness: was achieved by including a freshly random nonce with the transmitted data.

(P8) Linkability: was fulfilled by integrating the L3 pseudonym-Type1 in the L1 user's access credential. This pseudonym allows linkable access to patient data as it contains a lower-level pseudonym that can recover the patient's real identity, using the right secret key.

IV. Implementation and Performance Evaluation

In this section, we describe the implementation and performance evaluation of the LA security protocol. To achieve this, we have built a prototype using the Java 2 platform (standard edition), as it is suitable for e-health applications. It offers implementations for several cryptographic primitives and key management services needed for our solution.

Performance is measured by two metrics, minimising access delay and minimising server computation time. An access delay is defined as the time elapsed from submitting an access request to the time when the response to the access request is received. A server computation time is the time needed for the server to complete the necessary operations, verifications and checks from receiving the request to the time when the response to the request is sent. Both metrics should be kept as low as possible.

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To know the access delay and server computational time incurred by the LA protocol, we have measured the time taken to execute (run) the protocol based upon the prototype under two scenarios.

- In the first scenario (L3 Scenario), we run the protocol without applying an extra security layer to the protocol. This scenario is based on the principle of least privilege. This scenario is called the Level-3 access or the anonymous access scenario, which has been described in the introduction section.
- In the second scenario (L1 Scenario), we run the protocol with applying our additional security mechanism. This scenario is called the Level-1 access or the linkable access.

The measurements are taken for 10 execution rounds for each scenario, and the averages are calculated. The results are shown in Fig 3 and Fig 4.

A. Implementation Platform

To prototype the LA protocol, the following hardware and software have been used. We have used a desktop computer running Windows 8 with a 2.30 GHz Intel Core i3 and 8GB of RAM. The timing results from the LA protocol execution presented here are based on this computer specification. The software used to implement the LA protocol is JAVA 2 Platform, Standard Edition (J2SE).

B. Performance Evaluation Parameters and Target

The performance evaluation parameters we rely on are as follows.

- The patient's records are distributed in different databases which are managed by different HSP (e.g., hospitals). That is we run the simulation on a distributed manner and test its performance.
- Running the simulation where the database size of each HSP increases, patient wise and record wise. We first, run the simulation with the parameter 10 objects by 1000 patients and then we increase the object's size by ten and the patients' number by 1000.
- A single patient data request.

As we gave an real-life example in Section III-A, we show in the following section two things. (1) The time needed for the GP to obtain the patient's data. We call this access delay. (2) The time needed for each hospital to verify and complete the GP's request. We call this server computation time.

The target of the performance evaluation is to show that the LA protocol (Level-1 Scenario) offers a higher security than the protocol under the least access privilege scenario (Level-3 Scenario) and with a linear increase in performance. In other words, the LA protocol aims to balance between security and performance without adding a massive amount of overhead into the solution.

C. Performance Evaluation Result and Analysis

It can be seen from Fig 3 that the time (Access delay) taken to execute the LA protocol (L1 Scenario) is 1200 milliseconds in its peak, which is approximately 90% more than the time taken in the normal case or L3 Scenario, which is 101 milliseconds shown in Fig 4. The server computation time in L1 Scenario is 1150 milliseconds, which is approximately 91% more than that in L3 Scenario, which is 100 milliseconds.

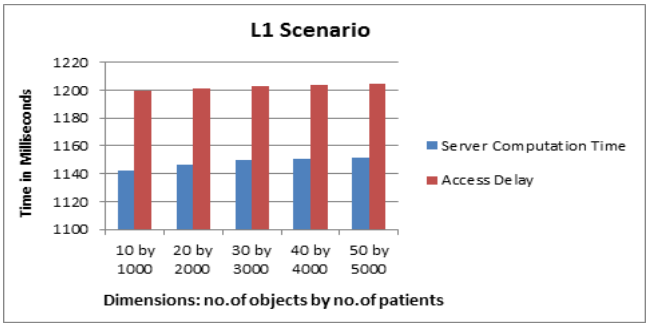

Fig. 3. Performance evaluation result of the LA protocol-L1 Scenario

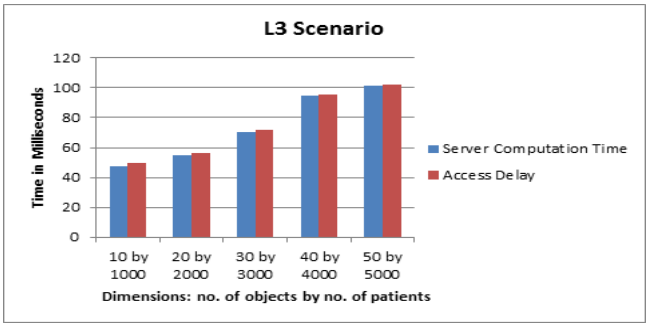

Fig. 4. Performance evaluation result of the L3 Scenario

The extra cost in the L1 Scenario is caused by the following reasons.

- The L1 Scenario contains three additional security layers, which were added on top of the L3 Scenario.
- The extra communications between the client and the verifier.
- The extra computations in signature verifications by both the client and the verifier.
- The extra computation in the attribute certificate verification by the verifier. In the L3 scenario, only PK-certificate verification is necessarily for completing the access request. No attribute certificate verification is involved in the L3 scenario.
- The extra computation in checking the timestamp in the attribute certificate.
- The extra computation in validating the pseudonym (PS3l1) included in the attribute certificate.
- The extra integrity check of the lower-level pseudonym (PS1) included in PS3l1.
- The extra computation in the decryption operation to retrieve or recover the patient's identity.
- The extra computation in signing the requested data or the response before sending it to the client.
- Finally, the extra cost in L1 Scenario between the server computation time and the access delay is due to the

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distributed patient's objects, which normally increases the waiting time. While in L3 Scenario a patient's objects are not distributed and are managed by a single HSP.

V. Conclusion and Future Work

In this paper, we focused on two major aspects. Firstly, the formal verification and security analysis of the LA protocol using Casper/FDR2 tool verification. Secondly, the formal performance evaluation of the LA protocol by building a prototype using the Java technology.

The result from the verification using Casper/FDR2 tool showed that the LA protocol has fulfilled important security requirements. It supports linkable access to patient data by integrating significant cryptographic techniques. It ensures confidentiality of patient sensitive data. It provides data freshness by relying on timestamps and nonces. It is protected from certificate manipulation and credential forgery. It ensures accountability by deploying digital signatures. Mutual authentication is also provided to obtain unforgeable proof of other participant's authenticity before it engages in the protocol with that participant.

In addition to fulfilling important security requirements, the result from the LA protocol implementation showed that the LA protocol had successfully balanced between security and performance. That is the increase in performance was linear with the increase of security. So our analysis proved that the LA protocol is secure and efficient. It allows a client and a server to exchange some sensitive patient data in a secure manner and within a reasonable amount of time. Our future work is concerned with extending our analysis of the LA protocol to other security protocols and specifically, e-health protocols, taking into account security and performance as major criteria.

Acknowledgement

This work is financially sponsored by the Ministry of Higher Education in Saudi Arabia.

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An Ontology-Driven Information Model for Interoperability of Personal and Electronic Health Records

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***Abstract*—Personal Health Records allow patients to maintain their own health information and are viewed as an important tool for patient self-management. However, uptake of these systems has been hindered by the large burden placed on patients to record information or to arrange for information to be transferred from other clinical systems. The favored option of transferring information from other systems is hindered by a lack of semantic and syntactic interoperability between Personal and Electronic Health Record systems. In this position paper, we describe the ongoing development of an information model that uses an ontology to ensure semantic integrity between concepts recorded by both types of record systems, and HL7 standards to maintain equivalent structure and function. The information model acts as a middle layer between record systems and thus is not tied to any specific Personal and Electronic Health Record implementation.**

Keywords - Personal Health Records; Electronic Health Records; Information Model; HL7;Ontology; Interoperability.

I. INTRODUCTION

Personal Health Records (PHRs) provide a summary of an individual's medical history and allow patients to view and edit their own medical data [1]. The aim of PHRs is to encourage patients to become more involved and informed as equal partners in their care, making positive choices to improve or maintain their health. Further, due to the increasing prevalence of long term conditions, patients' involvement in their care is viewed as potentially cost saving, and as such PHRs have become a strategic priority. For example, in the USA most Americans will have access to a PHR by 2014 if present Federal goals are accomplished [3], and Australia's 2011 budget mandated PHRs for all Australians to be achieved within 2 years [4]. However, despite much investment, adoption rates for PHRs remain low with causes such as lack of awareness, interoperability, and privacy and security concerns widely cited [5]. Although these are all important concerns, in particular, interoperability has been identified as a major barrier and in this research we focus on proposing a novel solution for PHR interoperability.

There are two prevailing models of PHR - "tethered" systems, which are sponsored by an organization and where the record is automatically populated without the patient needing to enter information, and "untethered" standalone systems which are entirely under the control of the patient who must enter their own information or arrange for it to be transferred from another system. As the majority of PHRs are untethered, the success of these systems is determined by a person's willingness to maintain their PHR information or on their health providers' willingness to share data from the patient's Electronic Health Record (EHR) so that it can be transferred to the PHR.

Although the tethered approach places fewer burdens on the patient it presents challenges for healthcare providers. The development of tethered PHRs usually involves the costly process of exposing selected parts of an organization's EHR to the patient by reprogramming or 'retrofitting' proprietary EHRs for purposes they were not originally intended [6]. As a result many tethered PHRs focus on providing simpler data to patients, for example, hospital visits or prescription drugs dispensed, rather than clinical data which requires gathering fragmentary information from multiple resources but which is necessary if patients are to be encouraged to self-manage in a meaningful way.

The aim of our research is to develop a framework to enable seamless interoperability between PHRs and EHRs in order to allow meaningful exchange of clinical data from providers to patients and vice versa in order to better encourage PHR use and patient self-management. The solution is equally applicable to tethered and untethered systems as it abstracts away from the specific PHR and EHR using an ontology-driven Information Model (IM) based on the HL7 Reference Information Model (RIM) that acts as a middleware layer between PHR and EHR systems. In this position paper we provide a description of the proposed IM for transferring information in a standardized way between EHR and PHR systems. In the next section we provide describe recent work on PHR interoperability. Section III describes the methods used to develop the middleware layer between EHR and PHR. Section IV presents a discussion and finally in Section V we outline some future work.

II. BACKGROUND

Our research proposes the use of an ontology-driven IM to address issues of semantic and syntactic interoperability between PHR and EHR systems. An IM is a representation of concepts and the relationships, constraints, rules, and operations that might be applied to these concepts for a particular problem space [7]. "An ontology is an explicit specification of a conceptualization" [8] and used to formally represent domain knowledge. Syntactic interoperability refers to the capability of communicating and exchanging data whereas semantic interoperability is the ability of systems to meaningfully interpret information exchanged.

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Recent work by Puustjärvi [9] focused on achieving semantic interoperability by developing a specific ontology for active PHRs. We borrow from this work but extend it to include syntactic interoperability using Health Level 7 (HL7) standards for data and document exchange [10]. Other research using HL7 standards for PHR interoperability has focused on messaging rather than full document exchange [11, 12]. In order to facilitate full document exchange, we have developed a general ontology-driven IM derived directly from common PHR data and functions. In addition, the proposed general framework provides a blueprint for developing new PHRs interoperable with EHRs.

III. METHODS

The process of developing the IM involved a number of distinct stages including an analysis of data and functionality available via common PHRs to determine information to be exchanged between PHRs and EHRs, a review of EHR and PHR standards, and designing and developing a middleware architecture for clinical document exchange. These steps are outlined in the following subsections.

A. Analysis of common PHR functionality

Initially 81 PHRs were accessed via myPHR web portal [13] and another 19 were selected based on a review by Carrión Señor et al [14]. By deciding to focus only on easily accessible free and web-based systems, 45 PHRs were selected. We applied a scoring system developed by [14] which assigns a utility score to PHRs based on data and access management, privacy and security settings and use of recognized standards. This resulted in the following 5 systems that scored>70% and thus were selected for detailed review:

1) *Microsoft Health Vault*
2) *Telemedical*
3) *NoMoreClipboard*
4) *Health Spek*
5) *Health Companion*

Due to the large variation among PHR systems, a template including a free text notes section was used to manually summarize functionality rather than a formal information extraction method. Table 1 summarizes extracted PHR information. Functionality has been separated into 6 categories which represent natural groupings of functionality: i) Patient Demographics and Other Family Members, ii) Care Provider Roles, iii) Clinical Record, iv) Interoperability, v) Social Aspects, and vi) Other Functionality. The last column ("Score") assigns a score reflecting the number of features available in each of the outlined categories and the last row of the table summarizes the total number of available features for each PHR.

TABLE I. ANALYSIS OF PHR DATA AND FUNCTIONALTY

Features	*Health Vault*	*Telemedical*	*NoMore Clipboard*	*Health Spek*	*Health Compa-nion*	*Score*
Patient Demographics and Other Family Members						
Personal Information	Y	Y	Y	Y	Y	5/5
Emergency Contact	Y	Y		Y		3/5
Emergency Card	Y		Y	Y		3/5
Em. Print-outs	Y	Y	Y			3/5
Add Other Family Members	Y	Y	Y	Y	Y	5/5
Friends					Y	1/5
Care Providers Roles						
Doctor	Y	Y	Y	Y	Y	5/5
Guarantor		Y				1/5
Insurance	Y	Y	Y	Y	Y	5/5
Pharmacy		Y	Y		Y	3/5
Provider	Y	Y	Y		Y	4/5
Clinical Record						
Allergies	Y	Y	Y	Y	Y	5/5
Condition	Y	Y	Y	Y	Y	5/5
Device	Y				Y	2/5
Diet	Y	Y	Y	Y	Y	5/5
Exercise	Y	Y	Y	Y	Y	5/5
Family History	Y	Y	Y	Y	Y	5/5
Imaging	Y			Y	Y	3/5
Immunization	Y	Y	Y	Y	Y	5/5
Labs	Y			Y	Y	3/5
Medication	Y	Y	Y	Y	Y	5/5
Procedures	Y	Y	Y	Y	Y	5/5
Social history		Y	Y	Y	Y	4/5
Supplement				Y		1/5
Surgery		Y				1/5
Vitals	Y	Y	Y	Y	Y	5/5
Wellbeing Considerations		Y			Y	2/5
Interoperability						
Import	Y	Y			Y	3/5
Export	Y	Y			Y	3/5
Import Documents	Y	Y	Y		Y	4/5
Connectivity with Devices	Y					1/5
Social Aspects						
Access Control	Y		Y			2/5
Groups					Y	1/5
Posts					Y	1/5
Share Medical Record	Y	Y	Y		Y	4/5
Other Functionality						
Appointment request		Y				1/5
Appointments	Y					1/5
Educational Information				Y		1/5
Health Goals	Y					1/5
Lab/Test Results Requests		Y				1/5
Manage Expenses					Y	1/5
Messaging		Y				1/5
Notifications & Reminders				Y	Y	2/5
Prescription		Y				1/5
Referral Request		Y				1/5
Refill Request		Y				1/5
Refills	Y			Y		2/5
Renews Request		Y				1/5
Risk Assessment					Y	1/5
Sent Payments		Y			Y	2/5
Visible Clinical Codes	Y					1/5
Emergency profile				Y		1/5
Web Visit		Y				1/5
Score	30/53	34/53	21/53	23/53	31/53	139

Considering the "Other Functionality" category in Table 1, the majority of components have a score of 1/5. Many of the functions associated with specific PHRs in this section are either slightly different to common functionality grouped in other categories or represents the same functionality from other categories only labelled in a different way. For example, the function of requesting lab results is additional functionality in Telemedical that allows users to requests lab results from third party applications but not to register results in the same way as in the other system (i.e. as part of the clinical record). This is an example of how similar functionality is implemented (lack of syntactic interoperability) as well as in nomenclature of similar concepts (lack of semantic interoperability) among PHRs.

B. PHR and EHR standards in use

HL7 RIM, HL7 CDA (Clinical Document Architecture), and messaging standards (e.g., HL7 v2.x and v3.0) form the backbone of EHR systems. RIM expresses the data content needed in a specific clinical context and provides an explicit

representation of the semantic and lexical connections that exist between the information carried in the fields of HL7 messages. CDA is an XML-based standard that specifies the encoding, structure and semantics of clinical documents for exchange. The v3 messaging standard defines a series of electronic messages to support all healthcare workflows [10].

The most common standards used for PHRs include the Continuity of Care Record (CCR) which specifies the encoding, structure, and semantics of a patient summary document. Furthermore, HL7 Continuity of Care Document (CCD) provides a template for representing vital signs, family history and plan of care [10]. In the case of the selected PHRs, CCD, CCR, and XML are used to import and export medical data. In most cases the imported documents are not fully embodied or merged with the patient's medical record; rather they can be seen as separate documents using Extensible Stylesheet Language Transformations (XSLT).

C. *Representing PHR data and relationships*

Our proposed IM, shown in Figure 1, consists of four classes to represent PHR data and relationships, namely: i) Role (participants), ii) Entity (roles are played by Entities), iii) Act (happenings) and iv) Element (data corresponding to Acts). The classes Role, Entity and Act have been preserved from the HL7 RIM foundation classes, however, both the use of each class and their relations have been altered. In RIM the class Role is related to the class Act through another class named Participation, and to the class Entity. In our IM, class Role is related to class Entity and the latter is then related directly to class Act. This is due to the fact that Roles in PHRs are more limited than in EHRs and thus Entities participate directly in Acts. The class Element has two subclasses named "Data" and "Unit" to manipulate represented data. These subclasses characterize data input or saved by a user as part of an Act. Sub classing data into its constituent Elements allows for finer-grained representation of patient data thus allowing the IM to capture variations among data stored by various PHR, as well as to adequately capture the greater number of data and data types stored by PHR when compared to EHR.

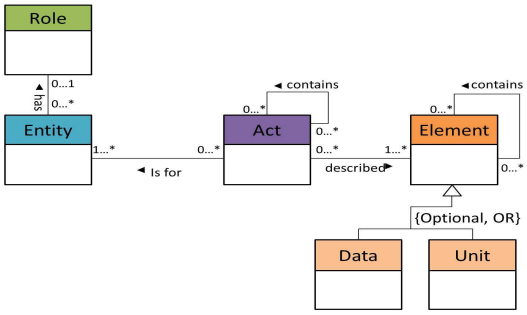

Figure 1. Information Model Classes

Figure 2 provides a sample scenario representing a patient monitoring their vital signs. A person (Entity) who is the patient (Role), monitors (Act) his vital signs (Element). Monitor is a composite Act that involves the measurement of different Elements. Moreover, a simple Element may consist of Data Elements or/and Units Elements). Data Element contains the actual value of a measurement (e.g. 120) and Unit Element contains the unit of measurement (mmHg).

Three of the proposed IM classes are used by HL7 RIM which is developed to accommodate any possible act in healthcare. Moreover the attributes of each class and the class themselves are flexible. Hence, it is expected that the proposed four classes can accommodate all relevant information for PHRs.

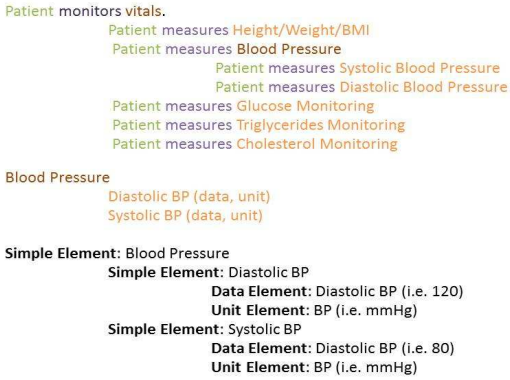

Figure 2. Sample scenario

D. *PHR – EHR semantic interoperability*

PHRs and EHRs may use different terminology to describe the same concept and thus obstruct data exchange between applications. To circumvent this obstacle the proposed IM uses an ontology developed using Protégé [15] and instantiated using Ontology Web Language (OWL) [16] as shown in Figure 3. The Ontology defines all classes described in the previous subsection along with their attributes, data properties (including cardinality and multiplicity) and relationships among them. This generic ontology may be instantiated for various PHRs.

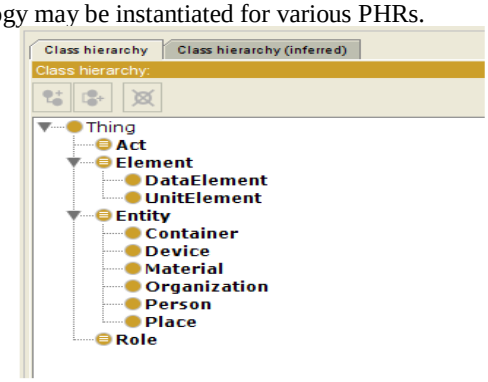

Figure 3. Information Model as an Ontology

By utilizing an ontology-based approach, semantic issues can be effectively addressed. For example, the declaration of equal features "Past Medical History" and "Previous Medication". Moreover, the use of Data Properties that can replicate coding schemas is also possible. For instance, the SNOMED CT code for past medication is "394829006". By assigning this code to Past Medical History, the meaning of these two individuals could also be interpreted as equal.

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E. PHR – EHR data syntatic interoperability

Data exchanged between PHRs and EHRs must conform to relevant structure and syntactic rules. In our framework, information will be transformed to and transferred as a CDA document; therefore the syntactic rules are the actual rules of the HL7 CDA standard. The CDA is represented in XML and an XML schema has been developed which is responsible for encapsulating all relevant syntactic rules. A PHP script is used to verify the XML schema.

F. Proposed Architecute

Our proposed architecture is shown in Figure 4. Data may be either exported from a PHR to an EHR or vice versa with the ontology-based IM instantiated as a middle layer between the two systems. This is in contrast to the system developed in [9] where transformations for exchanging data were embedded within the specific PHR and thus any updates to the PHR (e.g. addition or deletion of a field) must also be propagated through PHR transformations. We decided against such a specific solution to ensure greater scalability. Our middle layer solution ensures that when modifications are made to either a PHR or an EHR, they can be encapsulated directly by altering only the middle layer. The other prevailing approach (e.g. as in [11, 12]) is to create a domain specific IM called a Refined Message Information Model (RMIM) using RIM classes. As demonstrated in II.C, RIM is composed of pre-defined attributes which are difficult to change and generally not flexible enough for the wide variety of PHR concepts and associated data. Moreover, the use of RMIM emphasizes message exchange rather than the exchange of full medical records.

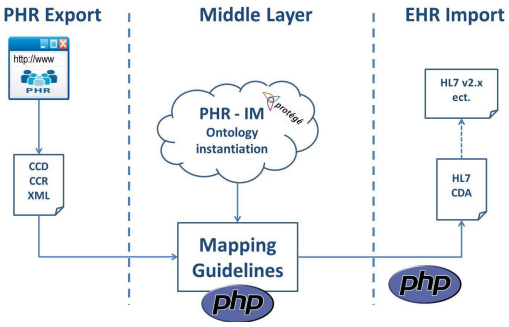

Figure 4. PHR- EHR architecture

IV. Discussion

Interoperability between PHR and EHR is a major barrier to PHR adoption. In this paper we have described ongoing development of an ontology-based IM for PHR to EHR interoperability. The proposed IM has been derived directly by analyzing common features and functionality of current PHRs. It extends HL7 RIM beyond EHR requirements to cover essential PHR requirements. Furthermore the instantiation of the IM as a middle layer between PHR and EHR systems insures additional flexibility by not tying the solution to any specific system. As well as being applicable to existing solutions (both tethered and non-tethered), the framework could be used as a blueprint to develop new EHR-interoperable PHR by allowing better flexibility both in the types and volume of information to be represented.

V. Conclusions And Future Work

The next stage of our research is to develop a set of mapping guidelines for transforming information from the ontology-based IM to CDA format. xPath and xQuery will be used to parse data exported from PHRs and EHRs and PHP scripts will be used to apply the required transformations and create the final CDA document. The guidelines will be evaluated using scenarios representing transformation of PHR data exported from CCR and XML format to CDA and vice versa. Longer term we intend to analyze PHRs that are not web-based or free of charge - primarily tethered systems - and make the required alterations to our framework accordingly.

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Medical Images Enhancement with Pseudo-HDR Method

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***Abstract*—Medical images are an important part of the diagnostic process. In many cases the accuracy of diagnosis depends on the quality of the image. Therefore, the image quality improvement is an essential part of medical imaging techniques. Now the quality enhancement process is divided into two parts: pre-processing, whose task is to optimize the image quality in the process of its creation by digital devices and apparata, and post-processing, whose task is increasing the readability and intelligibility of images on the physician's computer display. The proposed paper offers a new post-processing method for X-ray image quality enhancement using the theory of High Dynamic Range images (HDR-images). Since one could not get real images with different exposures, four techniques to simulate various levels of image exposures for HDR-image creation are proposed and analysed in the presented paper.**

Keywords - medical imaging; X-rays; HDR-images; quality enhancement.

I. INTRODUCTION

The investigation and development of new medical image processing methods and systems has received great attention over the last two decades. This is due to its wide range of applications in computer-assisted methods and computer-aided methods. Among the many types of image processing, image enhancement is one of the vital processes – it is one of the preparatory steps and it is applied before starting the image analyses. Image enhancement refers to any technique that improves or modifies digital images, so the resulting image is better suited than the original for a particular application. Essential image enhancement includes but is not limited to intensity and contrast manipulation, noise reduction, background removal, sharpening and filtering edges. In this context, 'image enhancement' means any method or technique which change digital images, so the resulting image is better suited than the original to a particular application. Due to this the basic types of image enhancement include manipulation of intensity, changing the local or global contrast, noise reduction, filtering and sharpening edges. During the image enhancement process one or more attributes of the image are modified. The choice of attributes and the way they are modified is specific to a given task. Moreover observer-specific factors such as the human visual system and the observer's experience will introduce a great deal of subjectivity into the choice of image enhancement methods [1].

X-ray images are grayscale images with 12-14 bits depth and their visual perception depends on the three most common image characteristics: brightness, contrast (local and global) and sharpness. Apart from these saturation and image dynamic range have a significant influence on the human perception of the images but they are not directly relevant to X-ray images, because images are grayscale (no saturation), and the dynamic range of the visualization systems (computer displays) is less than human vision dynamic range. Therefore, all quality enhancement methods change the intensity of pixels so as to provide optimal brightness, contrast and sharpness values. While brightness, contrast and sharpness may appear to be the simplest of image controls on the surface and may appear to be mutually exclusive controls, they are related and intertwined in such a way that changing any one of them can create quite complex effects in post-processed images. This specifies a wide variety of methods that have been proposed and are being created now – each of these methods seeks to solve the task of determining the image characteristics optimal values. A sample classification of medical image enhancement methods is shown in the Figure 1. [5][6][7][8]

This paper presents a new image enhancement method for X-ray images. The method uses HDR-image creation as a technique to increase the image dynamic range. This allows after mapping HDR-image to LDR-image (low dynamic range image) to get a better distribution of the intensity over all pixels in the image. The result is enhancing brightness, contrast and/or sharpness of images without the appearance of visible medical artefacts.

This present paper is structured as follows:

- Section II looks into the set of methods for HRD imaging
- Section III presents the proposed new enhancement method
- Section IV presents the implementation and analyses of the presented method
- Section IV presents the conclusion.

II. HDR IMAGING

A set of methods in photography/imaging, supposed to capture/create greater dynamic range between the darkest and lightest image areas than current standard digital imaging methods, is named High Dynamic Range Imaging [2][3]. The human eye covers the dynamic range of about 10^5:1 at one time and this is bigger than the top dynamic range of most real-world scenes. For comparison, computer

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displays have dynamic range of 10^3:1 and digital cameras have dynamic range of 10^4:1. In the last two years HDR cameras with dynamic range just over normal human vision dynamic range and displays with near to human vision dynamic range began to appear on the market.

The human vision can be accommodated to a dynamic range of 10^{14}:1 but the iris is simply not as flexible and the human perception of intensity changes is logarithmic (the Weber law). This is much more than the capabilities of modern devices for image creation and visualization. Therefore, a non-HDR image device takes pictures at one exposure level with a limited contrast range. This leads to the loss of details in dark or bright image areas, depending on the camera exposure setting. HDR methods compensate detail loss by taking multiple pictures at different exposure levels and stitching them together to create an image which presents the greatest number of details in both dark and bright areas. Data stored in HDR-images typically corresponds to the physical values of luminance/radiance that can be observed in the real world and this presents a great difference from classical digital images: classical digital images represent intensities and colours that should appear on an output device (display, printer, plotter, etc.). Therefore, HDR image formats are called scene-referred while classical digital images are called device-referred.

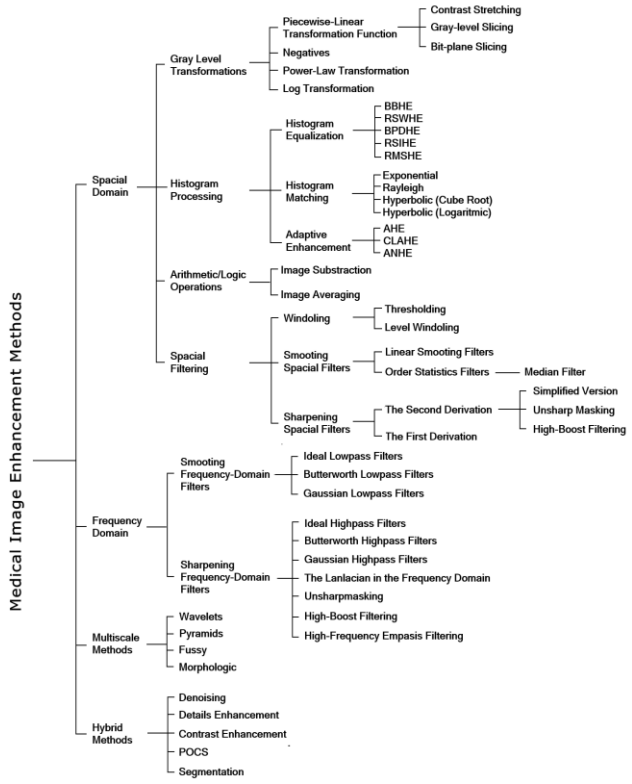

Figure 1. Medical image enhancement methods classification.

In photography dynamic range is measured in EV (Exposure Values) differences between the darkest and brightest parts of the image that show detail: an increase of 1 EV is a doubling of the amount of light. Using EVs not very strict categories of images are [4]:

- High Dynamic Range (HDR) images: These have a dynamic range of about 14EV and these images (they use 32-bit float values without limitation for channels bits depth) are usually produced by merging multiple 12-14 bit images of different exposures (most often these are raw data files).
- Medium Dynamic Range (MDR) images: These have a dynamic range of [9 EV, 12 EV] and can originate from a file with 16-bit depth, or by merging 3 or more 8-bit images with different exposures.
- Low Dynamic Range (LDR) images: These have a dynamic range of lover than 8 EV. This means one 8-bit image.

III. OUR QUALITY ENHANCEMENT METHOD

X-ray images are 12-14 bit grayscale images and their visual perception depends on the three most common image characteristics: brightness, contrast (local and global) and sharpness. Thus, when the image has no sufficient quality, this is the result of some incorrect values. As stored information in the grayscale images is the values for intensity of the image pixels, then all methods for quality enhancement are aimed at changing the pixel intensity as a way to change the basics characteristics of the image. This limits the opportunities for selection of optimal values, because a limited amount of information about the luminosity/radiance power stored as pixel intensity is used.

The method proposed below uses a different approach to solve the issue of the optimal intensity distribution over image pixels. Following this approach a model of the luminosity distribution is created instead, which has led to the current image. This is achieved by creating a HDR-image because it represents the description of the luminosity/radiance in the nature scene. After a HDR-image is created the method allows to determine the optimal mapping from a HDR-image to a LDR-image.

To achieve the correct results, it is necessary to establish a correct luminosity model of the simulated scene. For the HDR-image this is achieved by correctly selected additional images with different exposure. In photography this is achieved through capturing a new image with a selected exposure. Here this is not applicable and the main problem is to obtain an image that is accurate enough to simulate changes in the original image after changing the exposure.

From the image processing point of view increasing or decreasing the exposure changes the values of brightness, contrast and sharpness. Therefore, if the change of image pixels intensity resulting from the exposure change can be imitated, it can be used to simulate the image exposure change when a HDR-image is created. Our tests and analyses of results showed that for simulation a change in intensity a few different techniques can be used: using the brightness and the contrast control; using the gamma-correction; using the brightness and the contrast control followed by a gamma-correction; using the gamma-correction followed by a brightness and contrast correction.

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A. *Using the brightness and the contrast control*

One approach to solve the problem is based on the understanding that exposure change by 1 EV means doubling the amount of light. As the visual result is increasing of the pixels intensity for the entire image, the imitation of intensity shift requires calculation of brightness shift. Unfairness of this approach is that doubling the amount of light does not lead to doubling pixels intensity, because graphic devices and the characteristics of the created images reflect the human vision characteristics (logarithmic law for change of the intensity sensibility). Therefore, besides brightness there is also a considerable change in contrast.

Tests to determine brightness and contrast values were conducted: X-rays are captured with different exposures (from -3 EV to +3 EV by a 0.5 EV step) and the difference between the real image and the simulated image is evaluated to select values for brightness and contrast – Table 1 shows the results obtained for brightness and contrast (values of brightness and contrast are between -100 and +100). An example of -1.5 EV exposure simulations is shown in Figure 2.

TABLE I. EXPOSURE SIMULATION: GAMMA-CORRECTION VALUES

	Exposure (EV steps)					
		-2.5	***-2***	***-0.5***	***-1***	***-0.5***
Brightness		-81	-70	-55	-38	-21
Contrast		-35	-27	-20	-11	-5
	Exposure (EV steps)					
	0.5	***1***	***1.5***	***2***	***2.5***	
Brightness	22	40	56	71	83	
Contrast	6	16	26	34	46	

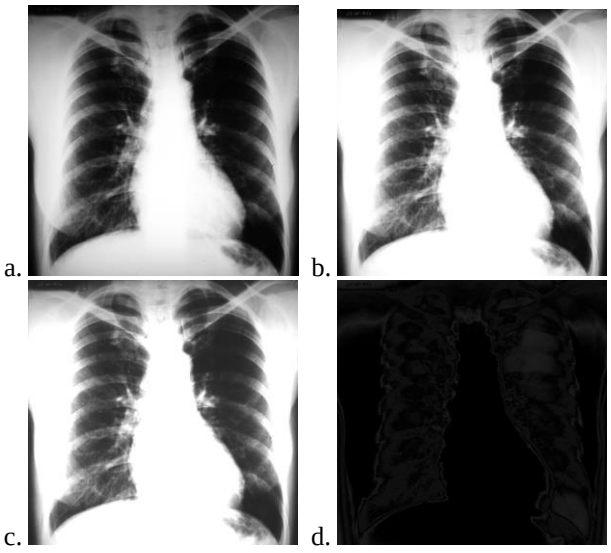

Figure 2. Using brightness and contrast control: a) the original image; b) the image with +1.5 EV; c) the simulated image with -1.5 EV; d) the difference between images (b) and (c) - the histogram is stretched twice in order to see the difference.

Our experiments show that simulation of exposures above 2.5 EV and below -2.5 EV is unrealistic and cannot be used for HDR-like image generation – when mapping to a LDR-image the result always contains medical artefacts. However, for bone X-rays, this approach gives very good simulations.

B. *Using the gamma-correction control*

Another way to simulate changing the intensity of pixels is by changing the gamma-correction.

The difference between brightness and gamma-correction control is that increasing the value of gamma-correction can make the image to look brighter, but it is a non-linear change and it only increases brightness of the shadows and mid-tones in the image without affecting the highlights. Our experiments showed that this is particularly useful for simulating the overexposed images or the lung X-rays.

Another significant difference is the ability to simulate exposure values in the range [-5 EV, +5 EV]. Figure 3 shows an example from Figure 2, and Table 2 shows calculated values for gamma-correction.

TABLE II. EXPOSURE SIMULATION: GAMMA-CORRECTION VALUES

	Exposure (EV steps)					
	-3	***-2.5***	***-2***	***-0.5***	***-1***	***-0.5***
gamma-correction	6.0	4.9	3.7	2.8	1.9	1.3
	Exposure (EV steps)					
	0.5	***1***	***1.5***	***2***	***2.5***	***3***
gamma-correction	0.81	0.71	0.6	0.52	0.45	0.4

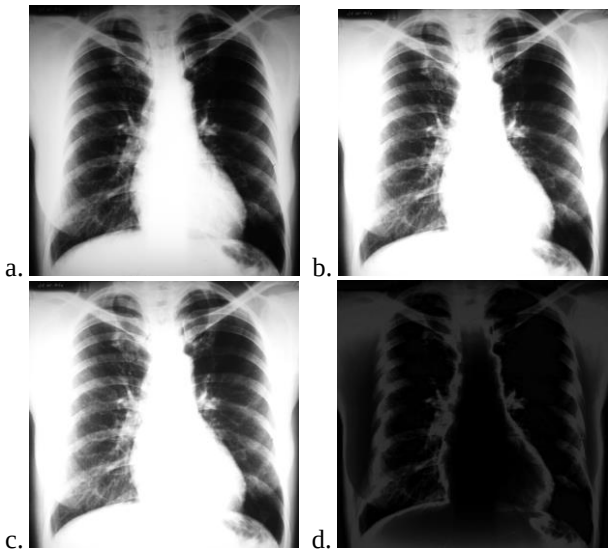

Figure 3. Using gamma-correction control: a) the original image; b) the image with +1.5 EV; c) the simulated image with -1.5 EV; d) the difference between images (b) and (c) - the histogram is stretched twice.

C. *Using the brightness and the contrast control followed by gamma-correction*

The main disadvantage of using brightness and contrast control is the incorrect change of local contrast between lung structures and ribs. That is why we tested additional image correction – the gamma correction. The result is a significant improvement of the simulation - Figure 4 shows the example from Figure 2, but now with the new way of correction. Table 3 shows calculated values for simulation of an exposure change.

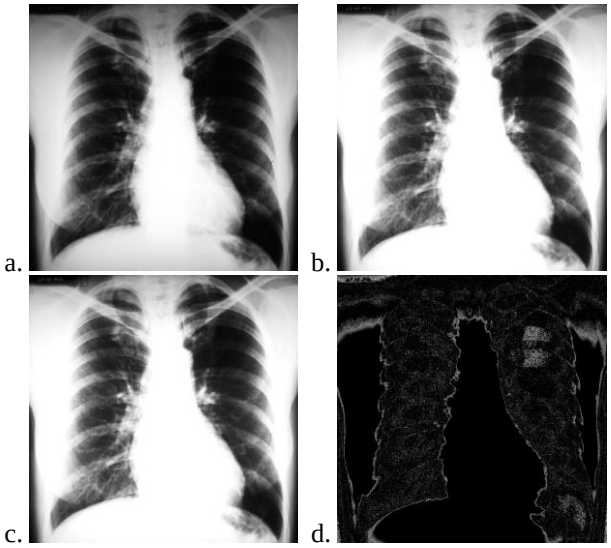

Figure 4. Using brightness and contrast control: a) the original image; b) the image with +1.5 EV; c) the simulated image with -1.5 EV; d) the difference between images (b) and (c) - the histogram is stretched 32 times.

TABLE III. EXPOSURE SIMULATION: BRIGHTNESS AND CONTRAST FOLLOWED BY GAMMA-CORRECTION

	Exposure (EV steps)					
		-2.5	***-2***	***-0.5***	***-1***	***-0.5***
brightness		-81	-70	-55	-38	-21
contrast		-35	-27	-20	-11	-5
gamma-correction		1.55	1.34	1.21	1.12	1.05
	Exposure (EV steps)					
	0.5	***1***	***1.5***	***2***	***2.5***	
brightness	22	40	56	71	83	
contrast	6	16	26	34	46	
gamma-correction	0.95	0.87	0.78	0.66	0.53	

D. *Using the gamma-correction control followed by brightness and the contrast correction*

The last approach to create an exposure simulation is gamma-correction control followed by brightness and contrast correction. This approach differs from the previous one, because the operations are not commutative. When comparing the result with the second approach, it appears that in this case the lighter areas are correctly changed. The result is the best simulation of exposure change of an image - Figure 4 shows the example from Figure 2. Table 4 shows calculated values for simulation of an exposure change.

Another advantage of the third approach is the possibility to simulate a much larger range of exposure values.

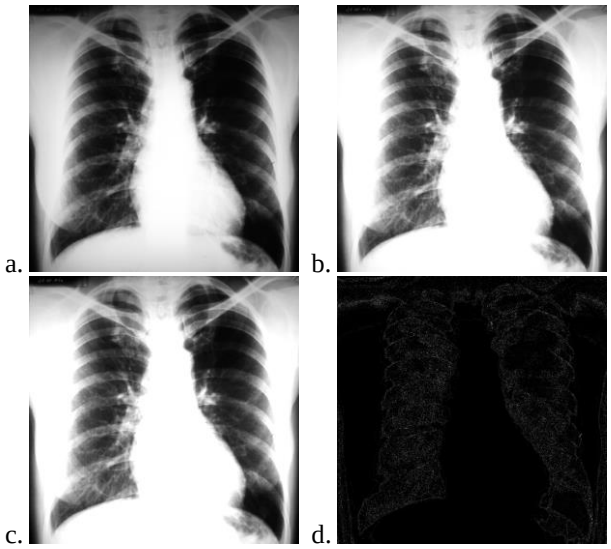

Figure 5. Using brightness and contrast control: a) an original image; b) an image with +1.5 EV; c) a simulated image with -1.5 EV; d) the difference between images (b) and (c) - the histogram is stretched 32 times.

TABLE IV. EXPOSURE SIMULATION: GAMMA-CORRECTION CONTROL FOLLOWED BY BRIGHTNESS AND CONTRAST CORRECTION

	Exposure (EV steps)					
	-3	***-2.5***	***-2***	***-0.5***	***-1***	***-0.5***
brightness	-52	-41	-26	-13	-4	-2
contrast	-55	-48	-34	-23	-17	-9
gamma-correction	6.0	4.9	3.7	2.8	1.9	1.3
	Exposure (EV steps)					
	0.5	***1***	***1.5***	***2***	***2.5***	***3***
brightness	6	14	18	22	25	27
contrast	7	17	24	32	38	42
gamma-correction	0.81	0.71	0.6	0.52	0.45	0.4

IV. METHOD IMPLEMENTATION AND ANALYSIS OF RESULTS

Using this method to enhance the X-ray quality gives a significant change even in the exposure values [0 EV, -0.5 EV, +0.5 EV] but in general this is not the best combination of values.

There are several different options for the number of LDR-images and their exposures from which the HDR-image will be generated – most common are 3 LDR-images

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with exposures [0 EV, -2 EV, +2 EV]. Our tests have shown that this set of exposures often leads to increased noise levels. So, as a standard set of exposure values, we used [0 EV, -1.5 EV, +1.5 EV]. This list of exposure values can be used in most cases, but for some specific purposes there are other parameters:

- In case of overexposed images, the best results are achieved with a set of 5 images with exposure values [0 EV, -1.5 EV, +1.5 EV, -2 EV, +2 EV].
- In case of underexposed images, the best results are obtained when using the set of exposure values [0 EV, -1 EV, - 2.5 EV].
- In case of X-rays of bones, good results are obtained with asymmetric values for the minimum and maximum exposure – for example [0 EV, -2 EV, +1 EV]. This set increases details in lighter areas (like bone structures).
- In case of lung or soft tissues X-rays, good results are obtained with opposite asymmetric values for the minimum and maximum exposure – for example [0 EV, -1 EV, +2 EV]. This set increases details in darker areas.
- In case of an image with a small dynamic range, a set of 5 images has to be used. This increases the details for all structures with different radiographic densities.

Another major advantage of the proposed method is the ability to manage the transformation from a HDR-image to the final LDR-image. This allows an optimal image quality to be obtained without the occurrence of medical artefacts.

The comparison of the results of the proposed method with other techniques showed that this method can help to obtain a major improvement in quality without the occurrence of medical artefacts. Especially important is the opportunity to use the same characteristics in all cases and always to get good quality – for example 5 images with exposure values [0 EV, -1.5 EV, +1.5 EV, -2 EV, +2 EV].

A few examples of the method implementation and comparison with Laplacian pyramids filter and CLAHE are shown in Figure 6.

V. CONCLUSION

Image quality enhancement is very important because it increases readability and understandability of the analysed images, their details and structure. When the exploited for image generation model is known this increases possibilities to correct the image without generation of medical artefacts. The presented method for pseudo HRD enhancements of medical images enables increasing quality of understanding and information gathering.

The next steps of this research are oriented to X-ray images of other body parts like bones, abdominal cavity, other soft tissues as well analyses of images from CT and other medical image sources.

ACKNOWLEDGMENT

This work is funded partially by the Bulgarian NSF under DO02/113 and DRNF02/3 projects.

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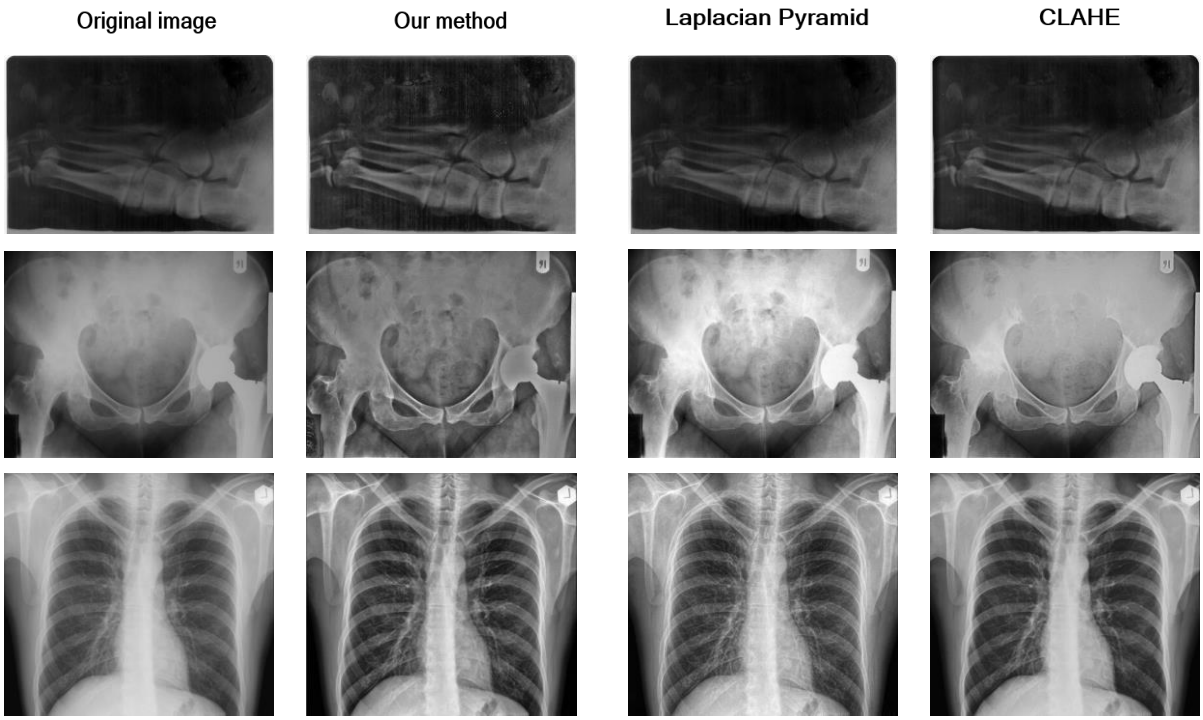

Figure 6. Comparison between our method, Laplacian pyramids and CLAHE: the proposed method improves contrast and details.

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Patient's rationale: Patient Knowledge retrieval from health forums

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Abstract— **Online health forums are areas of exchange where patients, on condition of anonymity, can speak freely on their personal experiences. These resources are a gold mine for health professionals—giving them access to patient to patient, patient to health professional and even health professional to health professional exchanges. In this study, we used text mining techniques to analyse health forums in order to extract emotions (e.g., joy, anger, surprise, etc.) expressed by patients. After a study of real messages, we demonstrate the difficulty of manual annotation due to the low level of agreement between humans. We propose a method to identify the polarity of a message and extract one or several emotions. This method was validated on a substantial real dataset.**

Keywords— Health forum analysis, emotion analysis

I. INTRODUCTION

Online health forums are areas of exchange where patients, on condition of anonymity, can speak freely about their personal experiences. Some examples are the very active forums, including healthforum.com[1], ehealthforum [2], which allow internet users (often non-health professionals) to exchange opinions on their health situation. Hancock [3] demonstrated that the ability to communicate anonymously via computers facilitates the expression of affective states such as emotions, opinions, doubts, risk fears, etc. These affective states are generally repressed in more traditional communication contexts, such as face to face interviews or when responding to surveys. These resources are a gold mine for health professionals—giving them access to patient to patient, patient to health professional and even health professional to health professional exchanges. For example, recently, the effects of new generation pills have been widely debated in French forums. This prompted some women to stop taking contraceptive pills, with a concomitant increase in abortions. Even if all patients do not use health forums, they represent a large and varied database of knowledge and patients' perceptions on their illnesses and any healthcare they have received. In this highly subjective setting, the characterization and understanding of these perceptions is difficult but nevertheless particularly relevant for complementing and improving public health programs.

As part of the French project called "*Parlons de nous*" ("Let's talk about us"), we tried to combine different markers (emotions, risk fears, uncertainty, etc.) with respect to medical items (drugs, treatments, etc.) in order to identify common collocations (e.g., between mediator and fear). In this article, we focus on the identification of emotions as a specific sentiment analysis task. While many approaches have been proposed for the analysis of text polarity (positive and negative), few approaches focus on the analysis of feelings (joy, anger, sadness, etc.). From a corpus of messages collected on the English-language Spine Health website, we used the vocabulary of emotions of Mohammad and Turney [4] to automatically annotate messages. A part of the corpus was manually annotated by 60 annotators. Based on a study of the agreement between annotators, we were able to show that it was difficult, even for humans, to associate a particular emotion to a message. We decided to give two information items to health professionals: the polarity of the text (positive or negative) and associated emotions (e.g., joy). We looked for the best descriptors for these two items. Experiments on real datasets revealed the effectiveness of this approach and discussions with health professionals have shown the medical importance of identifying such information.

The rest of this paper is organized as follows: in Section 2, we identify the medical issues. In Section 3, we propose a first sentiment analysis categorization and recent methods. In Section 4, we describe the corpus used in our approach. The method we used is described in Section 5. In Section 6, we describe the main results. Finally, in Section 7, we conclude and give the main prospects.

II. MOTIVATIONS

As pointed out by Siegrist [5], one of the great challenges for health professionals is to capture patients' satisfaction to answer the question "How can we improve our practice?". With this objective, Siegrist studied patients' feedbacks after their stay in large American hospitals and turned them into raw data that could be tapped by the medical authorities for decision making. Using the forums as an object of study, we are getting closer to the patient private sphere. Indeed, patients express things in posts, they does not express in comments (even anonymous). However, precisely identifying the emotional state of patients through these messages is a difficult objective task and not always verifiable, as discussed by Quirk [6]. However, we could consider using these large amounts of emotionally-charged texts to construct indicators that are relevant for health professionals. An example of such an application is "We feel fine" [7]. This tool queries the web with the aim of assessing users' moods. Every 10 minutes, the application considers

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sentences with emotional words and performs statistical calculations based on the type of feelings, age, gender, etc. An example of application is dedicated to pharmaceutical companies. They monitor the social web in general to identify texts in which patients talk about their medications and measure the associated emotional states. This feedback can help them improve their products or their communication about these products. Another example concerns the physicians who want to know the patients fears about the prescribed treatments. This feedback can help them to improve their communications to patients.

The (semi-)automatic analysis of forums is difficult from a technological standpoint. Most (semi)-automatic methods used in the health domain are applied to publications and hospital reports. Adapting these methods to messages from social media like forums is not simple at all. Such messages are written by patients in rather a loose style. They vary in size (between a hundred and a thousand characters). They contain non-standard grammatical structures, many misspellings, abbreviations, emotion-rich expressions as well as emotion-rich words (I love, I hate), unconventional lay-out, e.g., repeated use of capital letters (TIRED), unconventional spelling (enooooooough), and punctuation repetition (!!!!!!!!), slang words that are (or not) specific to the forum or the topic (LOL vs. IVF) and emoticons (:-)). Message volumes are generally very high (in the French forum dedicated to breast cancer on the Doctissimo site, there are more than 3,300 threads, some of which contain more than 2,000 replies). Finally, the processing of health forum data based on semi-automatic information extraction methods is a significant technological challenge.

III. STATE OF THE ART

Sentiment analysis has been widely studied since the early 2000s. Many communities are interested in this area and their definitions and interpretations are highly varied (e.g., psychology, social sciences, computational linguistics, natural language processing, data mining, etc.). Sentiment analysis involves the extraction of emotional states expressed or implied in texts [8]. It includes the following tasks:

1. Subjectivity analysis [9] focuses on the detection of feelings based on subjective expressions or words;
2. Polarity analysis [10] focuses on the detection of positive and negative polarity of texts;
3. Emotional analysis [11] focuses on the emotional category of texts (e.g., anger, disgust, fear, etc.)
4. Intensity analysis [12] focuses on different levels of polarity or emotion intensity (e.g., very positive, very sad, etc.). These approaches offer a more precise granularity of expressed opinions and emotions.

We focus on the third task. Like most semi-automatic methods in the literature, we use the typology of emotions defined by Ekman [13], which describes six emotions, but many other typologies also exist ([14]; [15]; [16]).

The methods used to analyse feelings are numerous and generally specific to the text type, e.g., tweets [17], press titles [18], *etc*., and application areas, e.g., social media analysis [19], gender impact in negotiations [20], identification of suicidal emails [21].

For all studied sentiment analysis tasks (polarity and emotions), most previous studies focus either on the creation of resources to describe feelings or on the use of these resources to classify texts according to sentiments. In the first category, most methods associate texts with emotional word resources. Most of these resources have been compiled for English texts and polarity analysis, e.g., General Inquirer [22], Linguistic Inquiry and Word count [23], MicroWNOp [24], sentiwordnet [25]. More specific resources, such as the DAL dictionary [26], Wordnet affect [27] or the lexicon of Mohammad and Turney [4] were created for emotional words. There are also approaches for extending these vocabularies for specific application domains by building manual rules [28], or identifying co-occurring words with words already identified as denoting emotions through large corpora [29] or the web [30]. For classification, most approaches use machine learning techniques based on specific attributes, including emotion words ([31]; [18]) to build a statistical model from a corpus of texts and use it to detect feelings in other texts.

While many of these methods are effective on large text corpora, they are limited in the case of short texts such as tweets or specific texts as in health forums. In our study, these limitations were mainly due to the subjectivity of the annotation task, as we describe in Section 4.2.

IV. CORPUS

A. Data collection and annotation

We built a corpus from 17,000 messages collected in the English-language Spine-health forum. We automatically annotated the corpus with the vocabulary of emotions of Mohammad and Turney [4]. This lexicon consists of more than 14,000 entries characterized by their polarity and associated with 8 emotions. In this work, we consider only 6 emotions (Ekman, 1992): anger, disgust, fear, joy, sadness and surprise.

Each word in the lexicon could be associated with several emotions (e.g., the word abandoned was associated with the emotions fear, anger and sadness). This automatic annotation enabled us to filter 22% of the messages (not containing emotion words). In order to focus only on emotions associated with medical items, we used MeSH to identify medical units in the text, which allowed us to filter messages without any medical references (6% of messages). In a message, many emotions were usually expressed because the messages were relatively long. We therefore chose to segment the messages in sentences. We finally kept 3,000 sentences to constitute an Automatically Annotated Corpus (AAC) and labelled sentences with several emotions by the most frequent one (re-annotation step).

A subset of this corpus (600 sentences) was manually annotated by 60 non-health professionals, i.e. basically Master's students and computer science researchers from our lab. We called this the Manually Annotated Corpus (MAC). We thus set up a web-based platform. Unlike Strapparava and Mihalcea [18] who used an interface to annotate and capture many emotions through an emotion-intensity cursor, we decided to simplify the task and asked the annotators to

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identify only the presence of emotions expressed in the texts. Each sentence was pre-labelled automatically via the lexicon, the corresponding emotion was shown by default but could be unchecked if the annotator believed that it was not expressed in the sentence. If the sentence did not express any emotion, all emotions were to be unchecked. Finally, if the annotator could not decide, "I do not know" was selected.

Table 1 shows the distribution of sentences in both corpora according to six emotional categories. The AAC corpus was clearly unbalanced and both fear and sadness emotions were best represented. In the MAC corpus, 45% of the sentences were annotated as neutral (no emotion) and 9% were undecidable. We also noted after the re-annotation that the MAC corpus was better balanced than the AAC corpus. However, surprise was very poorly represented.

TABLE I. PERCENTAGE OF SENTENCES IN BOTH AAC AND MAC CORPORA ACCORDING TO 8 CATEGORIES (J – JOY, SU - SURPRISE, F - FEAR, A - ANGER SA - SADNESS, D - DISGUST, N - NEUTRAL, DK - DO NOT KNOW) BEFORE AND AFTER RE-ANNOTATION.

AAC	J	Su	F	A	Sa	D	N	DK
Before	22	14	39	22	39	18	/	/
After	13	4	33	9	35	6	/	/
MAC	J	Su	F	A	Sa	D	N	DK
Before	10	4	17	13	19	14	45	9
After	14	6	23	14	25	18	0	0

B. Between-annotator agreement

We used the Kappa measure to assess the between-annotator agreement. For this, 150 sentences from the MAC were annotated by two non-professional annotators. We got a Kappa of 0.26, which clearly shows that the agreement between annotators was very low. In addition, we measured the agreement between health professional annotators and non-professionals for the same 150 sentences and obtained a moderate agreement of 0.46. This preliminary experiment highlighted the difficulty of the manual annotation task. Moreover, the disagreement between annotators was mainly due to the variability between people and not their sensitivity to health (professional vs. non-professional).

A first bias, already identified by [32], was in considering the perspective of the annotator/reader likely differed markedly from that of the author of the message. Indeed, health forum posts treat topics such as disease, treatment, etc. This information is negative by nature and most of the annotators, by empathy, associated an emotion such as sadness to factual information such as the description of a diagnosis. For example, the sentence "I am also HLA-B27 negative, so was diagnosed with a spondyloarthropathy" was annotated as sad in our corpus, although it contained a factual diagnosis. A second bias concerned the fact that the corpus was in English, while the annotators were native French-speakers. Furthermore, by studying sentences with gaps in the annotations, we noticed that it was easier to identify the polarity than the emotion. It was also easier to predict positive emotions than negative emotions because negative emotions share very similar vocabulary. We also noted that surprise was the hardest emotion to identify, as also noted by Strapparava and Mihalcea [18] who argue that surprise is not often taken into account in studies of emotions as it is neutral in nature. For example, the sentence "I discovered its effect on me the hard way, hugging the toilet after a painful back procedure, ugh!" None of our annotators considered the emotion surprise, despite the presence of the word "discover".

The quality of our annotated corpus was actually quite questionable. Indeed, the annotators were not sufficiently coached with specific instructions to avoid the biases mentioned above. Tests of internal consistency (inter-individual reproducibility) would have to be done to assess if the annotators were consistent over time. Another possibility would be to get several annotators to annotate sentences and choose labels by majority vote. Finally, even with its drawbacks, this study gave a relatively clear picture of the difficulties involved in obtaining a qualitative corpus and the methodology to improve its quality. Based on these findings, we then decided to compare the results obtained with the AAC and MAC corpus, knowing that most of the methods of the state of the art only use AAC corpus. We evaluate different methods to characterize forum texts based on: 1) a two-category classification to identify the polarity of emotions; 2) a multi-category classification for six emotions: a sentence could only be associated with a single emotion class. Surprise was eliminated because of its neutrality. This typology is similar to that described by Roberts [17]; 3) a multi-label classification allowed us to associate a sentence to several emotion classes.

V. EXPERIMENTAL PROCEDURE

Our approach relies on a classification method based on attributes such as unigrams, bigrams and specific attributes, defined to capture traces of emotions in messages. It consists of two steps: 1) pre-processing of sentences from messages, and 2) classification of these sentences. Evaluation of the results depends on the classification performed.

Pre-treatments: forum posts are specific in the sense that the words used are not necessarily found in conventional dictionaries (slang, special formatting, abbreviations, emoticons, etc.). It is therefore necessary to standardize them by generalizing their content. To do this, we applied the pre-processing procedure outlined in Table 2 and corresponding to the chain set up by (Balahur, 2013) for tweets.

TABLE II. APPLIED PRE-PROCESSING

Pre-processing	Example	Resource
Repeated punctuation	!!!!	/
Specific layout	TIRED	/
Emoticon	:-)	/
Slang	2mr > Tomorrow	Chatslang.com
Emotional words	Fear	Mohammad's lexicon [4]

Classification: We used the following attributes in order to find the best emotion descriptors:

– Attributes based on N-Grams (U, U+B): Unigrams, Unigrams and Bigrams;

– Emotion words (EW): if a sentence contains two words corresponding to the emotion joy, it takes the value 2 for the corresponding attribute;

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– Smileys (SMI): all emoticons (:-):-(...) were classified according to the six emotions. If a sentence contains a smiley related to joy, it takes the value 1 for the corresponding attribute;

- Amplifiers (AM): These attributes correspond to punctuation (!,?...), repeated letters (looool) and capitalized words (HATE). If a sentence contains such elements, it takes the value 1 for the corresponding attribute;

- The emotion context (CONT): we used two attributes that we call neighbour emotion and overall emotion. The first attribute is true if the sentence that precedes or follows the sentence expresses the same emotion and the overall feeling is the true value if there is another sentence in the message that expresses the same emotion.

Like Bechet [33], we enriched the attributes with patterns obtained using a sequential pattern algorithm (PAT). For this, we used the MeSH medical thesaurus to identify medical words (labelled MW), the lexicon of emotion words (labelled EW) to identify traces of emotions and a lemmatizer for grammatical category words (labelled JJ, NN, VV, MD, etc.). Each sentence was then considered as a sequence of itemsets corresponding to a combination of these three labels. We then used the GSP algorithm [34] to obtain frequent patterns, i.e. frequent sequences. We used only those containing at least one label for a medical entity and another label for an emotion word. These patterns were then used as attributes. A sentence was labelled true for a pattern if its syntactic form fit the pattern. Figure 1 summarizes the protocol for obtaining patterns.

Initial sentence:
Chronic pain may cause secondary depression

Emotional and Medical word tagging:
Chronic/MW pain/EW/MW may cause secondary depression/EW/MW

Grammatical tagging:
Chronic/MW/JJ pain/EW/MW/NN may/MD cause/VV secondary/JJ depression/EW/MW/NN

Sequence:
MW/JJ EW/MW/NN MD VV JJ EW/MW/NN

Figure 1. Sequence definition

Evaluation: The quality of the two-class classification was evaluated using the standard precision measurements *P* (percentage of correct predictions), recall *R* (percentage of correct labels found by the system) and F-measure *F* (harmonic mean of precision and recall). For multi-class classification, we calculate both the average *Fmi* at a micro level (*R* and *P* were calculated by constructing the overall contingency table) and *Fma* at a macro level (*R* and *P* were calculated for each class and averaged). For multi-label classification, other metrics were needed. Indeed, if we took, for example, a sentence belonging to both classes sadness and anger, the system could predict: sadness and anger (the prediction was correct), sadness (the prediction was partially correct) and disgust (the prediction was wrong). So there were degrees of possible misclassification. Other measures [35] were then used such as the Hamming loss *HL* (accuracy for each class averaged per class), accuracy *A* (averaged for all examples) and macro F-measure *Fma.*

VI. RESULTS AND DISCUSSION

We used implementations of Weka for bi-class and multi-class classification and Meka for multi-label classification. We used the SMO implementation of the SVM classifier of Weka with default settings. We used the CC chain classification implemented in Meka for multi-label classification. We used two datasets: MAC and AAC corpora (considering that the majority emotion label set after automatic annotation was the class to predict). We carried out a cross-validation (10-fold) and used the attributes described in Section 5. Table 3 presents the AAC corpus results. We do not present the MAC corpus results which were similar that seems to suggest that even with the previsous limitations mentioned in Section IV.B, the MAC corpus has at least the same quality as the corpus used in the literature and obtained automatically from emotional word ressources.

TABLE III. COMPARISON OF RESULTS OBTAINED ACCORDING TO A SET OF ATTRIBUTES USING THE AAC CORPUS

	Bi-class			M-class		M-labels		
Attributes	R	P	F	F_{mi}	F_{ma}	HL	A	F_{ma}
U	62.7	57.8	60.1	24.4	23.2	0.24	51.5	58.2
U+B	65.9	61.5	63.6	24.8	22.3	0.14	58.3	59.3
U+B+EW	66.3	64.1	65.1	**27.3**	25.1	**0.12**	**61.4**	61.8
U+B+EW+SM+AM	53.4	52.4	52.9	23.4	20.7	0.25	55.5	55.8
U+B+EW+CONT	53.6	45.5	49.2	25.2	22.5	0.22	55.4	57.6
U+B+EW+PAT	66.2	65.2	**65.7**	26.1	**25.8**	0.15	58.2	**62.4**

The bi-class classification gave the best results, which seemed fairly consistent because the two classes were better represented. This task was also easier for human annotators. Multi-label classification gave better results than the multi-class classification because one example could be associated with multiple classes. Moreover, we detected only little differences between the micro and macro F-measures for multi-class classifications, which suggests that all classes were hard to identify. These results should be compared with the inter-annotator agreement (see section 4.2). In both cases, the task was difficult, but the semi-automatic method seemed to detect patterns more systematically, except in specific cases such as irony.

We could also conclude that the best descriptors were a combination of unigram and bigram with emotion words (U + B + EW). Taking smileys and amplifiers into account did not improve the classification. Indeed, smileys were often used for irony, which was not captured by considering their presence in the sentence. For example, the sentence "I stopped working in 1/09 and kind a thought that at some point I would get better, in hindsight, also rather dumb:-) instead of picking up the pace of getting worse significantly" was automatically associated with the label joy because of the smiley:-), even though it was used by the patient to indicate his bitterness. A simple improvement consists in changing the polarity of the smiley if in the near context there is a contradictory polarity.

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Similarly, the context was not an attractive attribute. Indeed, messages were often long (7 sentences on average in our corpus) and contained many feelings (more than 6 emotions in 41% of the messages). Two consecutive sentences often contained different uncorrelated emotions. Finally, patterns were also ineffective because they were too general. They could easily be used to improve the accuracy if we define them by class of emotion.

Note that when the classifiers were wrong, they often placed the sample in a "close" class, with the same polarity. These incorrect predictions were due to the fact that the classes shared many words (such as anger, disgust and sadness). Dictionaries and lemmatizers are used as resources, so the method could easily be applied for other languages using similar resources.

VII. CONCLUSIONS AND PERSPECTIVES

Here we describe a method for analysing emotions in health forums. The main challenge was the acquisition of annotated data, and this step will be further improved. For the extraction of emotions, we compared different attributes for different classification tasks (two-class, multi-class and multilabel) and showed that the most effective were a combination of unigrams and bigrams and emotion words for classification bi-classes. However, suggesting a precise label, despite the precision obtained, could be relevant for the health care professionals involved in such studies.

[36]Prospects associated with this work are numerous. From the emotion analysis standpoint, we will apply our method on larger datasets not specific to health, such as the SemEval challenge [37] and compare our method with other published methods such as SWAT [38], uPAR [31] and UA [30]. We will also take shifters into account. Indeed, Smith and Lee [36] showed that the polarity of a term is often modified by the context surrounding it, including markers of negation. In the sentence "This treatment does not make her happy", the negation changes the polarity of the sentence from positive to negative. In the case of emotions, it is harder to understand the impact of these shifters because there are close links between emotions, such as between the failure to be happy and to be sad. For this, more complex emotion models should be used, such as SentiSens [39] which takes the relationship between emotions into account (e.g., hate vs. love). In addition, we will build a lexicon of emotion words specific to our area, as proposed by Carrillo de Albornoz [39]. For this, several options are considered. Smith and Lee [36] used Wordnet [40] to associate new words with words already associated with an emotion based on the relationship *"similar to"* for adjectives and hyponymy for nouns and verbs. Inspired by the Turney and Littman approach [41], it is also possible to search for frequently co-occurring adjectives (or other grammatical forms) using the web or large corpora [30]. We will also validate the genericity of our approach on a French corpus. Indeed, our method relies solely on lexicons and a stemming tool. Finally, the attributes used in our study are focused on the expression of emotions through the lexicon and not through the syntax or through other discourse markers. An improvement would be to integrate these aspects, although complex rhetorical constructions are not frequent in the studied forums.

We also identified issues related to the field of application. The spine-health forum is specialised in the topic of "pain" and discusses a pathology which is a disease of the elderly. The nature of the text message is closely related to these two factors (little smileys or slang, little expressions of joy, etc.). To explore other feelings, we need to diversify the themes of the studied forums. Once the emotions are identified, many applications can be envisaged. The discovery of novelties such as medical associations between medical entities and emotional markers can be used for informational searches by laboratories (e.g., what patients think of this medicine?), physicians (e.g., what patients think of this operation?), patients, etc. More generally, emotion searches could be used to model variations in emotions over time. For example, over time we frequently observed changes in the emotions of patients, e.g., "fear and surprise", "surprised and angry", etc. Furthermore, we could study the influence of the media on the patients' emotion changes, e.g., the case of the third generation pill. Another application might be to identify patients communities based on the expressed emotions. For example, in the debate about the effects of new generation pills, it was noticed that many of the comments were related to religious beliefs. This information is essential for moderators. This applications list is not exhaustive. Identification of emotions is a step toward these applications.

ACKNOWLEDGMENT

This paper is based on studies supported by the Maison des Sciences de l'Homme de Montpellier (MSH-M) within the framework of the French project *Let's talk about us* (*Parlons de nous)* [42].

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Context-Oriented Data Processing for Homecare Application

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***Abstract*—Due to growing numbers of elderly and increase in chronic diseases, many homecare systems have been proposed in order to improve the quality of care and social assistance services. These systems are based on using advanced technologies such as sensors in order to ensure a continual patient's monitoring and support contextual information provided anywhere and at any time. Effectiveness and efficiency of homecare solution depends on the capability of processing the large amount of data acquired through sensors in a continual basis. This paper addresses this issue and proposes an extensible approach aiming to process and filter data in real time in order to distinguish between normal and abnormal situations, detect alarm conditions and store only relevant information. To process data and take into account patient's physiological and environmental changes, a sensors-based context model and context-based rules are defined.**

Keywords—Context model; homecare system; rules management; sensors; data filtering; alarm situations.

I. INTRODUCTION

In recent years, face to growing numbers of elderly and increase in chronic diseases, many homecare applications have been proposed in order to improve the quality of care and social assistance services [1][2]. Financially, living in a smart home is preferable to living in a nursing home, which is quite expensive [3]. These applications integrate various advanced information and communication technologies such as sensors [4], wireless communication, ubiquitous computing [5], etc., which support ubiquitous information provided anywhere at home and at any time in order to ensure a continual patient's monitoring. However, effectiveness and efficiency of long-term condition care depends on the capability of processing data gathered in continual basis and proposing adequate services to the patient.

This situation confronts us with various challenges: (1) sensors generate a large amount of data in a continual basis, (2) data are not all necessary for use, (3) data should be analyzed immediately when received in order to detect alarm situations, (4) data should be filtered at home to eliminate irrelevant data before being transferred to health care professionals, and (5) sensors can change according to the development of the patient's situation.

In light of these challenges, we are proposing a home care solution capable of processing data locally at home. The motivation of this research is to design an approach aiming to filter data according the patient's care needs. It provides an extensible prototype for monitoring and handling sensed data. This approach is based on using sensors in order to collect data on the patient's everyday life. For this, managing the context in which the patient lives becomes a primordial requirement in order to support any changes in the patient's status and environment.

The prototype we develop will be implemented in a local application located in the patient's home for two reasons. Firstly, data have to be filtering locally in order to send only useful information to health professionals. Secondly, critical situations should be taken into account immediately in the form of available services without waiting for the opinion of a health professional.

This work is considered as a first phase of a complete project capable of processing data or external requests (for example, from professional health care) in order to propose and manage personalized services according to the patient's needs and preferences. To release this goal, the prototype we develop should be generic and extensible in order to cover all patients' needs and to adapt to any patients' preferences.

In this research, three processes are identified: alarm, storage and delete processes. Defined context-based rules are used for separating between normal and abnormal data and analyzing normal data in order to make decision to store useful information and reject useless data.

We note that we are not concerned to collect data from sensors. We suppose that data are available to be processed in an exploitable format.

The paper is organized as follows: Section 2 discusses related works. Section 3 presents the architecture of the system. Section 4 discusses about the modeling of context model based on using sensors. Section 5 presents the modeling of different rules useful for filtering data. Section 6 explains the data acquisition process. Section 7 shows the different steps for data processing mechanism. We will end the paper with a conclusion and future works.

II. RELATED WORKS

Nowadays, many researchers have been interested in elderly and dependent people needs, particularly in Europe [6], and proposed homecare systems such as Ambient-assisted Living [7], Remote patient monitoring [8], location

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tracking, patient behavior modeling, etc. in order to recommend adequate solutions related to long-term monitoring of patient's activity and homecare assistance [9].

This convergence of homecare systems enables elderly and dependent people to stay at home and receive human care in a much quicker and easier manner [10][11]. These systems have mainly focused on the patient's data acquisition through data monitoring devices such as sensors placed either directly on the patient's body for collecting individual data (temperature, heart rate, oximetry, etc.) or at the patient's environment for detecting distress situations (patient falling, fire, abnormal movement, etc.) [12]. Sensed data are then transferred to a central server via wireless communication technology to be analyzed by medical professionals in order to make decisions in consequence of them.

In recent years, we have noticed that a homecare system providing a patient remote care is closely combined with the notion of context which is more commonly considered in context awareness systems [13][14]. A context is mainly defined as any information that can be used to characterize the situation of entity as the location, the time, the preferences, etc [15]. This concept has been mostly used in ubiquitous computing systems [16] and, more recently, in Ambient-Assisted Living (AAL) domain in order to locate users anywhere and propose services at anytime according to the user's status and environmental conditions [17]. The contextual information acquisition and processing are among the main challenges identified in the AAL systems and performed by a central middleware [18]. Most of the context-based healthcare middleware centralize the data processing transferred from homes and focus on detecting critical situations. Moreover, most of researches in homecare domain are very specific to particular needs such as detecting alarm situations. However, to be more efficient and adaptive, it is more interesting to be able to cover all daily patients' needs by abstracting from the different contextual situations in order to filter data, which specify the context and propose social assistance accordingly. In our opinion, the core of the application should be designed in a contextual independent way, i.e., by defining different contexts in which it will be used. In this paper, we are taking into account this challenge by proposing a data processing mechanism capable of filtering data in order to propose personalized and auto-trigged services in function of patients' needs.

III. ARCHITECTURE OF PROPOSED APPLICATION

The main objective of this research is to design a data processing mechanism responsible for filtering contextual data acquired through sensors according to the patient's care needs. The filtering process consists in analyzing sensed data in real time in order to distinguish between abnormal and normal situations and eliminate irrelevant information. Abnormal status concerns with critical conditions which need to be detected and handled immediately, whereas, normal status designates either the need to store data for a later use or simply to ignore them if no use. As a matter of fact, in normal situations, some gathered data are needed for specific tasks decided by health professionals (for example, writing a report once a day at 6 p.m on the patient's state).

Thus, the data processing mechanism refers to three steps: 1) alarm process for detecting critique situation, 2) storage process for testing if data need to be stored and 3) delete process for deleting useless data.

Fig. 1 presents a functional description of the mechanism which consists of four modules: 1) acquisition of data, 2) data processing mechanism, 3) context-based rules, and 4) sensors-based context management. The first one describes how collected data are stored in an exploitable text format before being processed.

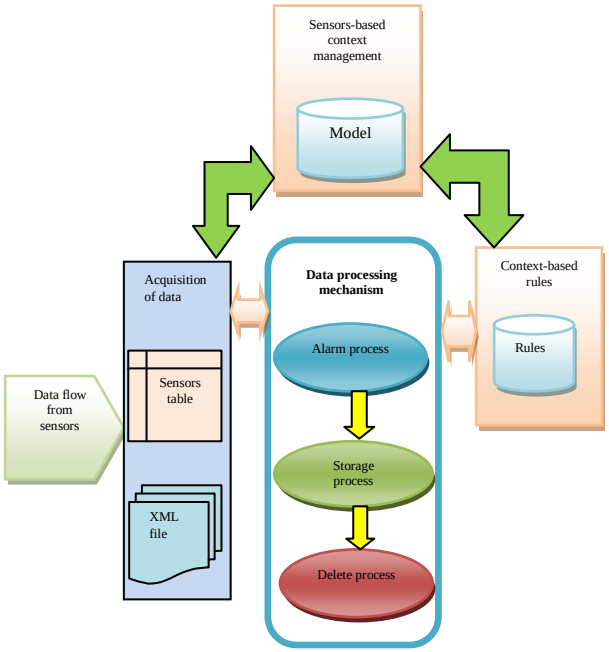

Figure 1. Functional description of the application.

The second one explains the different steps of performing the alarm, storage and delete processes in order to filter contextual data. The third module defines the context-based rules used in the data processing module in order to reason over the contextual information. The latest module creates a sensors-based context model served to represent a generic description of sensors and sensed contextual information. Each of these modules will be presented in detail in the next sections.

IV. SENSORS-BASED CONTEXT MANAGEMENT

In general, a home-based care system relies on using sensors located anywhere at home in order to provide information on patient's daily-live conditions and the home environment. Thus, one of our key requirements is to manage sensors efficiency and easily by identifying their characteristics, their roles and their locations and by providing a description of contextual information collected from sensors. To do this, a generic, reusable and extensible sensors-based context model is proposed in order to facilitate adding new sensors, updating or deleting sensors at any time if needed.

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Because the rules definition and the data acquisition modules use the high description of the sensors-based context model, it is important to be able to start with defining the sensors implemented at the patient's home through the model.

Fig. 2 represents an abstract description of sensors-based context model. A *patient* is characterized by a *context* which is identified by a set of sensors categories. Each *category* is composed of sensors or other categories. A *sensor* is described by a set of *sensorInfo* which describe the roles and the characteristics of the sensor. Each sensor is sensed by a set of composite context parameters represented by the entity *complexContextP*.

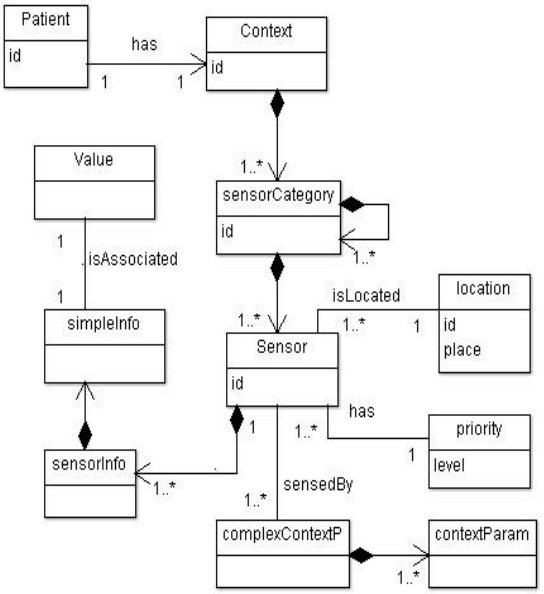

Figure 2. Abstract description of sensors-based context model

These parameters give a high description of data extracted from a given sensor. A *complexContextP* entity is composed of *contextParam* entities which designate simple context parameters. The entity *location* represents where a sensor is located at patient's home. The entity *priority* represents the priority associated to a sensor. We identify three levels of priority: high (1), middle (2), low (3).

Fig. 3 represents an example of concrete structure of sensors-based context model. This example identifies two categories of sensors: activity and environment sensors. Accelerometer and Temperature are two sensors. Accelerometer and temperature sensors are located at the bedroom. Info designates sensorInfo entity. Role is a simpleInfo entity which has a value "detect walk". Accelerometer sensor is sensed by a contextParam "action".

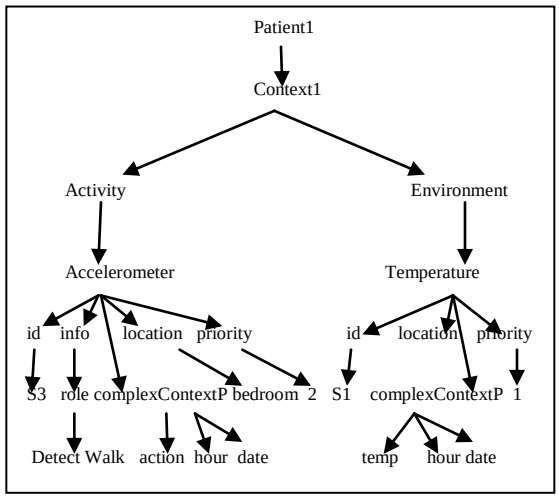

Figure 3. Concrete sensors-based context description

V. DEFINITION OF CONTEXT-BASED RULES

Once the sensors and their characteristics have been defined through the sensors-based context model, the rules useful for the data processing mechanism could be determined. These rules are applied on contextual data extracted from sensors what involves a relationship of dependence between sensors and rules (Fig. 4).

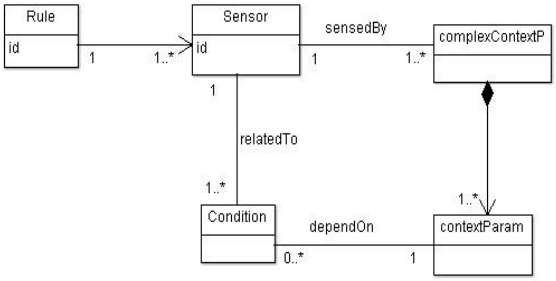

Figure 4. Abstract context-based rules model

A rule is generally defined as a collection of one or several elementary conditions. Each condition depends on a sensor which means that one rule is associated to one or several sensors which regroup one or multiple elementary conditions (Figure 4). If a sensor is related to one condition, the latter is simply represented as a child node of sensor. Otherwise, conditions related to a sensor are interconnected by links named connectivity. We distinguish two forms of connectivity {AND, OR}.

Fig. 5 illustrates an example of a rule with four conditions C1, C2, C3, C4 related to a given sensor, these conditions have to be connected with AND and/or OR. We suppose that C1, C2 and C3 are interconnected by AND and this collection is linked to C4 by OR.

Therefore, we notice that these conditions are structured in three levels (Fig. 5). Level 1 is for OR, level 2 is for

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AND or/and elementary conditions and level 3 for representing elementary conditions.

An elementary condition is composed of three parts: *contextParam*, predicate and value. *contextParam* designates an entity already defined in the sensors-based context model. As a rule is applied on data extracted from sensor, the use of the entity *contextParam* is highly justified. The predicate designates one of these possibilities {<, <=, >, >=, =, !=} . The value can be a number or a text.

The manner of defining rules facilitates adding new rules for any process and updating existing rules. As the main objective of this application is to test if collected data from sensors is concerned with alarm, storage or delete cases, rules are then classified in two groups: alarm rules responsible for detecting alarm situations and storage rules which test if collected data must be stored for a later use.

We will explain the use of these rules more in detail in the next section.

```
<rule id=1>
    <sensor id =3>
      <OR>
        <condition id='C4'>
          <contextParam>param1</contextParam>
          <predicate> = </predicate>
          <value>45</value>
        </condition>
      <AND>
        <condition id='C1'>
          <contextParam>param2</contextParam>
          <predicate> = </predicate>
          <value>45</value>
        </condition>
        <condition id='C2'>
          <contextParam>param3</contextParam>
          <predicate> = </predicate>
          <value>29</value>
        </condition>
        <condition id='C3'>
          <contextParam>param1</contextParam>
          <predicate> = </predicate>
          <value>48</value>
        </condition>
      </AND>
    </OR>
  </sensor>
</rule>
```

Figure 5. An example of a rule

VI. ACQUISITION OF DATA

The data acquisition introduces the way in which contextual data are represented to be exploitable by the data processing mechanism. In this research, we consider that contextual data are received by our application in a final format available to be analyzed. To deal with data, the data processing mechanism requires two basis:

- A table in which active sensors are declared
- XML files used to insert collected contextual data

The table represents the identifications of sensors which are in action and send contextual data. This table is organized according to the sensors emission frequency. Two cases are possible: at a frequency f, we can have either one sensor which send data or several sensors which act together.

Other more important factor which needs to be precessed is the priority between sensors. Indeed, each sensor has its own priority level already defined in the sensors-based context model by the priority entity. Therefore, sensors should be ordered and handled in order of priority. Once active sensors are specified in the table, our mechanism verifies their priority level and then classifies them in three levels: high, middle and low. Table1 illustrates an example of the sensors representation. S1 and S2 are two sensors with high priority, S3 a sensor with middle priority, whereas S4 a sensor with low priority.

TABLE I. EXAMPLE OF SENSORS REPRESENTATION

Priority / **Frequency**	Low	Middle	High
f1	S4		S1 ; S2
f2		S3	S1
f3	S4		S2

The second facet of the data acquisition part consists in representing contextual data in XML files. This step is not discussed in this research. We work on the assumption that contextual data is organized in XML files and available to be handled in the data processing mechanism. The structure of a XML file is based on the sensors-based context model and more specifically by the entities: sensor, contextParam, complexContextP. Fig. 6 gives an example of a part of xml structure.

```
<sensors>
    < sensor id='S3'>
      <complexContextP>
        <action>walking</action>
        <hour>8.30</hour>
        <date>25/12/2013</date>
      </complexContexP>
    </sensor>
    <sensor id='S1'>
      <complexContextP>
        <temp>37</temp>
        <hour>8.30</hour>
        <date>25/12/2013</date>
      </complexContexP>
    </sensor>
</sensors>
```

Figure 6. Example of XML structure

VII. DATA PROCESSING MECHANISM

The mechanism mainly consists in filtering data stored in XML files as described in the data acquisition section. Sensors which generate these data are specified in a sensors table. The filter process is based on using rules defined in the context-based rules module. We have two types of rules: alarm and storage rules. Each rule contains conditions

related to given sensors. Fig. 7 illustrates the different steps of the data processing mechanism. Firstly, we test if data are abnormal or normal. Then, we verify if data should be stored or deleted.

The filter process is performed in various steps:

1) For each row of the sensors table, we have to calculate all combinations between sensors. This calculation is made in function of the priority of sensors. We remind that we have three levels of priority: high, middle and low. We start with sensors which have high priority. We pass then to sensors with middle priority. Finally, we terminate with low priority sensors. We illustrate this calculation by an example.

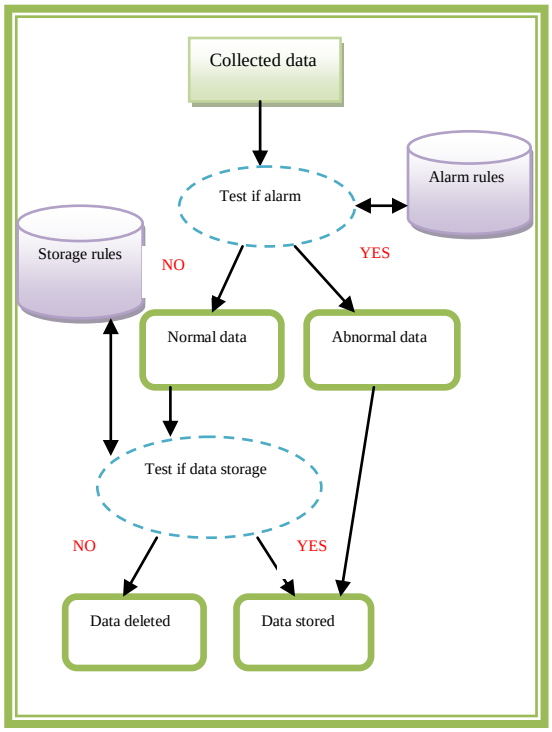

Figure 7. Data processing mechanism

In row1, there are three sensors

- S1-S2 with high priority
- S4 with low priority

- Firstly, we start by calculating combinations between high priority sensors S1 and S2 which has as result: S1, S2, S1-S2.
- Secondly, as we do not have middle priority sensors, we pass to low priority sensors. We have one sensor S4. Then one combination is calculated = S4.
- Finally, we calculate combinations between sensors S1, S2 and S4. We have as result: S1-S4, S2-S4, S1-S2-S4.

The calculation of combinations has as result

C = {S1, S2, S1-S2, S4, S1-S4, S2-S4, S1-S2-S4}

2) Once combinations are found, the second step consists in looking for rules which correspond to sensors designated in each combination. As we have alarm and storage rules, we start by alarm rules because alarm process is more priority to take into account.

For each combination c of C, we have two possibilities:

- Rules corresponding to sensors of c are not found => next combination
- Otherwise, conditions contained in each rule are extracted in order to form a XML query

The formed query will be executed on the contextual data stored in the xml file. The execution of the query returns either 1 or 0.

- 1 => data are abnormal
- 0 => data are normal

The first case triggers an alarm situation and data storage

The second case triggers the storage process

3) For normal data, we have to test if data need to be stored or deleted. Similar to alarm process, the same steps are applied on the combinations of C. We research if there are storage rules which correspond to sensors contained in each combination. If it is the case, a query is formed which will be executed on the xml file. We can have two responses:

- 1 => data storage is needed
- 0 => data can be deleted

Once these different tasks are ended up, we can delete xml file which contains data under process and pass to next row of the sensor table.

The next step in this research consists of triggering services in function of patient's needs. In this paper, we do not develop this point, but we can give an idea on which our next research will include. In principle, each rule is associated to one or many services as described in Figure 8. Once a rule is found and its formed query returns 1 as a result, services related to this rule is triggered to execute tasks defined for selected services.

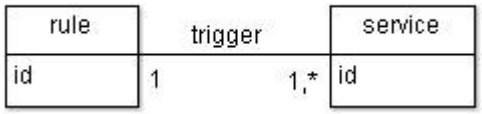

Figure 8. Relationship between rule and service

Thus, we have described the different steps needed to process and filter data generated through sensors and stored temporarily in xml files.

VIII. CONCLUSION AND FUTURE WORK

In the paper, we have presented an approach capable to process and filter data acquired through sensors locally in order to classify them in three categories: alarm data to detect alarm situations, relevant data to be stored for a later use and irrelevant data to be eliminated. We remind that the

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main objective of this application is not to trigger alarm situations, but only to indicate there are abnormal data which need to be taken into account immediately or normal data.

This work is the first step in a project, which consists of assisting any patient at home whatever the situation, needs and preferences he has. To achieve this goal, a generic and personalized view is proposed in order to consider any new adding or change in the daily patient's context. For this, a sensors-based context model has been designed for characterizing sensors and contextual data. Context-based rules have been defined for reasoning over contextual data. This application has for advantage to eliminate irrelevant data at patient's home and transfer only useful data. Extensibility and configurability of the context-oriented data processing mechanism behavior may be achieved by extending the context-based sensor model with new concepts or specializations of existing ones and by adding/modifying reasoning context-based rules. This application can be easily extended with using specified services in order to satisfy patient's needs and provide personalized access to patient's data.

Presently, we are planning to implement the approach in java to evaluate and test the success of the prototype from a scenario. The second step is about using and managing services in order to improve alarm management and real-time monitoring. We are also thinking about managing profiles needed for defining all patients' characteristics such as pathologies, disabilities, preferences and personal data in order to propose to the patient personalized services. Finally, we will also consider actors involved in a different extent in the care of a patient such as patient's relatives, doctors, nurses, the care center, etc.

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User-Centered and Persuasive Design of a Web-Based Registration and Monitoring System for Healthcare-Associated Infections in Nursing Homes

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***Abstract*— Patient safety is increasingly threatened by healthcare-associated infections. To cope with this threat, insight into the occurrence of such infections is paramount. We used a holistic approach for the user-centered and persuasive development of a system for the registration of healthcare-associated infections in nursing homes. To do so, we combined multiple methods (literature search, expert discussion, questionnaire, interviews and scenario-based user-tests), closely cooperating with end-users. This study shows why involving end-users in all stages of development is of paramount importance for the creation of successful eHealth technologies.**

Keywords-User-centered design; Persuasive design; Web-based; eHealth technology

I. INTRODUCTION

Healthcare is increasingly confronted with threats caused by Healthcare-Associated Infections (HAIs) [1]. To be able to adequately protect patients from this threat, one of the first steps is to gather knowledge on its occurrence [1]. For hospitals, already a vast amount of surveillance data is available [1-7]. For other healthcare institutions (such as nursing homes), prevalence studies have more recently begun to take place. The results of the first prevalence study of HAIs in Dutch nursing homes were published in 2011 [8].

To enable prevalence research in nursing homes, data must be collected on all clients that are present in the nursing homes at one point in time. The success of such data collection is entirely dependent on the willingness and capability of the elderly care physicians to register their clients in a correct and timely manner. Preferably, the registered data should be collected in a standardized way to fit other (e.g., nation-wide) surveillance programs [1]. One way to achieve this is via the use of a standardized registration system, that allows users to collect, process, and analyze surveillance data.

We developed a registration system to optimally support elderly care physicians in the correct and timely registration of their clients, taking into account the national prevalence studies [2] with which collected data should be compatible. We aimed to do so, by applying user-centered and persuasive design to the development process.

The research question is: How can user-centered and persuasive design improve the registration of HAIs in nursing homes by elderly care physicians? Aim is to make the new registration system reliable, fitting within work processes, and faster, easier and clearer than the current registration method.

First, the methods that are applied in this study are described: the analysis of the current situation via expert discussion (section II.A.); the analysis of the users' needs via a questionnaire study (section II.B); and the analysis of the user-friendliness and persuasiveness via in-depth interviews and scenario-based tests with end-users (section II.C.). Then, the results of the different study methods are given: a description of the current situation (section III.A.); the users' needs and values (section III.B.); the use of persuasive systems design in the prototype (section III.C.); and the user-friendliness of the prototype (section III.D.). Finally, the performed study is discussed (section IV) and conclusions are drawn (section V).

II. METHODS

The Center for eHealth Research and Disease Management (CeHRes) has developed a roadmap (see Fig. 1) that is used as a framework for the holistic development of eHealth technologies [9]. It incorporates principles from business modelling, human-centred design and persuasive design within five development cycles [10, 11].

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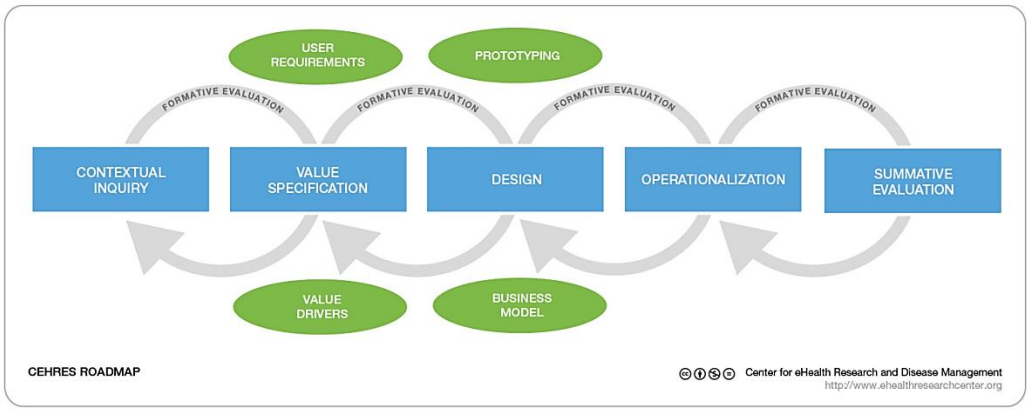

Figure 1. CeHRes Roadmap [9].

A. *Analysis of Current Situation via Expert Discussion*

This project started with a request from iPrevent [12] to aid in the development of a new 'mobile' registration system. iPrevent is a regional infection control network within which healthcare institutions, elderly care physicians, medical microbiologists and Infection Control Professionals (ICPs) work together to structurally offer high quality care in the field of infection prevention [12].

To gain insight into what iPrevent specifically wants or needs from this project, and into the prerequisites for the registration system, an expert discussion was held, with two project leaders (one of whom is also the data analyst) and two behavioral researchers. The outcomes of the discussion were complemented with literature on the registered HAIs and national surveillance.

B. *Analysis of Users' Needs via Questionnaire*

Based on the expert discussion a questionnaire was developed, to gain insight in what values end-users had (concerning a registration system) and whether the project aims match these values.

A total of 24 physicians who worked at different nursing homes within the iPrevent network participated in the study. Their age ranged from 30 to 61 (mean age 47 years). Most participants were female (19 female vs. 5 male).

Questionnaire results are analyzed to obtain descriptive statistics. Statistical analyses were deemed redundant, given the developmental purpose of the study. Answers that are given to open-ended questions, were summarized if they overlapped and then their frequencies were analyzed.

C. *Analysis of User-Friendliness and Persuasiveness via In-Depth Interviews and Scenario-Based Tests with End-Users*

To validate the questionnaire data and to optimize the user-friendliness and persuasiveness of the prototype, scenario-based user-tests and in-depth interviews with end-users are performed.

Four female elderly care physicians who worked in different nursing homes within the iPrevent network participated. Their ages varied from 33 to 59 (mean age 45 years). One of the nursing homes they worked at, already used Electronic Client Files, the others will start to do so in the near future.

Based on the analysis of the context and of the users' needs, and in close cooperation with an ICP, a prototype of the registration system was developed using Balsamiq software. The prototype incorporated elements of Persuasive Systems Design (PSD) [13]. Not all elements of PSD were deemed relevant for this system, but as much elements as possible have been applied.

Two scenarios were developed for the user tests. They were developed by an ICP and made use of literature on the HAI definitions. The scenarios addressed critical issues for registration.

The physician was instructed to talk out loud during the entire user-test, not only mentioning what she thought, but also what she saw or sought, did or wanted to do.

The entire conversations (including both interview and user tests) took about 45-60 minutes each. Audio recordings of the conversations were transcribed verbatim and analyzed using a code book. Some examples of the codes are given in Table 1. All codes were combined and the frequencies with which they were mentioned were analyzed.

TABLE 1. EXAMPLES OF CODES USED FOR ANALYSIS OF USER-TESTS

Examples of codes used for data-analysis		
Category	***Code***	***Description***
Contextual Inquiry	C1	Subject describes a problem that is experienced in the current work process
Value Specification	V1	Subject thinks working with the new system might be faster
Design	D1	Subject thinks the order of the items in the mock up is wrong
Operationalization	O1	Subjects talks about a possible barrier for using the new system

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III. RESULTS

A. Current Situation

iPrevent has over the last years worked together with the approximately 30 nursing homes within their network, to perform annual prevalence measurements for nursing home infections. This means that elderly care physicians are required to once a year register all relevant data about the residents that live in their nursing homes. Inherent to the fact that it is a prevalence measurement, all clients must be registered within a short timeframe around a reference date.

The content of the registered data is largely determined by the definitions of HAIs. These definitions were developed by the regional network in cooperation with the national surveillance system (PREZIES) [14]. In the hospital setting, surveillance is performed by trained infection control nurses. The use of the definitions in the nursing home setting, where registration is performed by physicians with little or no experience with surveillance, registration is far more complicated. The currently used registration system translated definitions into questions, but did not offer the physicians any additional support. The prior registration system used a SurveyMonkey questionnaire for registration. The questionnaire consisted of a long list of complicated questions. Many of them are irrelevant for most residents. For example, if a client does not use an antibiotic, the question about what an antibiotic is used for, is rather redundant. Also, all questions are presented on a single page. Physicians thus have to scroll down seemingly endlessly, past irrelevant questions, while scanning to find questions that are relevant, all the way down to the bottom of the page, before they can start with the registration of the next resident.

Furthermore, an increasing amount (>30) of nursing homes participate in the prevalence measurements that iPrevent performs. Thus, increasingly large datasets are collected. Data processing, data analysis and presentation of feedback of the results to the nursing homes are all performed by a single data-analyst. This will soon no longer be feasible. Project leaders (and the data-analyst) therefore would like the system to perform these tasks automatically.

Finally, project leaders requested that the new system would be 'mobile' (to be used on a smartphone) to enable bedside registration of clients by elderly care physicians.

B. Users' Needs and Values

The questionnaire resulted in insight in the context of the problem and in the users' values. When asked what kind of device they would like to use for the registration, most subjects indicated they preferred a PC (50,0%) or laptop (20,8%). The other subjects preferred to use a smartphone (12,5%), tablet (8,3%), or paper (8,3%).

Most important reasons for users to be willing to use the new registration system were: (1) if they can interrupt registration without losing data; (2) if the new system is more user friendly; (3) if it can be opened simultaneously with Electronic Client Files ('Elektronisch Cliënten Dossier' in Dutch); (4) if clear insight is given in the results; and (5) if registration can be performed faster.

One of the prerequisites that were found during the expert discussion said that it would be desirable if registration could be performed at the residents' bedside. This would enable the physicians to directly see how the resident is doing. However, the questionnaire showed that none of the physicians considered this to be desirable. Most of them (54,2%) did indicate that it would be of added value for them to be more flexible in the location in which they register their clients, but didn't want to do so bedside. Also, 41,7% said that it would not be of added value at all since they just liked to register their residents in their offices. One physician (4,2%) wanted to register her clients in the department's office, with the client files at hand.

Yet, the in-depth interviews gave even more insight into the situation. Physicians explained that their nursing homes were (going to be) using Electronic Client Files (ECF). This is software that contains highly personal and private information about the residents. Therefore, many safety measures have been taken to protect this information. Because of one of these safety measures it is impossible to simultaneously open the ECF and the World Wide Web. In practice, this meant that elderly care physicians had to open the ECF, and write down all the information about all of their clients that they needed to register in the prevalence measurements. Then they had to close the ECF and open the SurveyMonkey questionnaire and enter the information they had written down. Not to mention that if they had forgotten any information, the entire procedure had to be repeated. The subjects therefore did want registration to be possible on a mobile device, but for reasons that differed from what was expected, i.e.: so they could simultaneously open the ECF on their pc and the registration system on the other device.

C. Use of Persuasive Systems Design in the Prototype

1) Primary Task Support

One of the main concerns with working with the prior registration system was that working with the SurveyMonkey questionnaire required the physician to read through many irrelevant questions for every client. One of the most important elements of PSD that were to be used in the new system was therefore *tunneling* [13]. The prototype system was designed to guide the user through the system, questions to be answered are dependent on the answers given to prior questions. Thus, the entire system is a big decision tree, to make sure every client is registered via the shortest (fastest) possible route.

Another concern with the prior registration system was the complexity of the used questions (which were based on definitions of HAI). To reduce the complexity, and thus the risk of interpretation errors, *reduction* was used. The aim of reduction is to reduce complex behavior into simple tasks, to help users perform the target behavior [13]. This was

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done by translating complex and long questions into a flowchart consisting of multiple questions. For example, the originally used question for Gastro-Enteritis, was rather lengthy and complicated (see Quote 1).

> Does the resident have Gastro-Enteritis? The diagnosis Gastro-Enteritis is given if one of the following symptoms occurs in the client:
> - Three times or more diarrhea (different from normal for this client, frequency is not applicable when using incontinence materials)
> - Diarrhea and two of the following symptoms: fever, vomiting, nausea, stomach ache, stomach cramps, blood or mucus in feces.
> - Vomiting three times within 24 hours, without any additional symptoms (if vomiting is not associated with medicine use)
> - Vomiting and two of the following symptoms: fever, nausea, stomach ache, stomach cramps, blood or mucus in feces.

Quote 1. Question about Gastro-Enteritis in the prior registration system (Originally in Dutch)

This question was translated into shorter and simpler questions divided into several screens. Some of these screens are shown in Fig. 2.

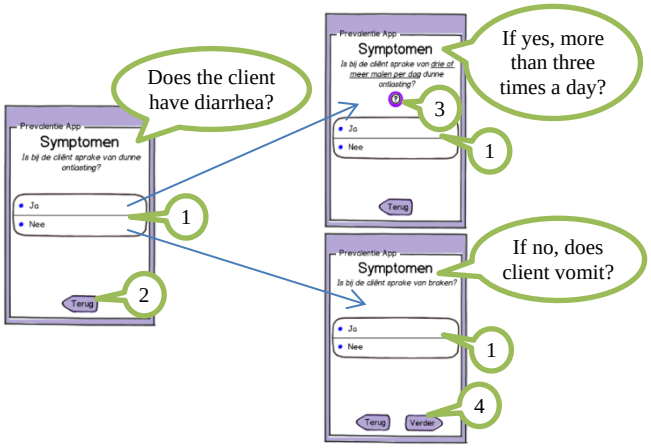

Figure 2. Part of the screens of the prototype used for Gastro-Enteritis; Example of Reduction: *(1) Answer options: Yes / No; (2) Button to return to previous screen; (3) Help-button for additional information; (4) Button to continue to next screen.*

As mentioned before, it was of great importance that registration would be faster and could be paused without losing data. To enable this, elements of *tailoring* are applied to the prototype, which allows the system to be tailored to (in this case) the usage context factors [13]. Every nursing home was given a unique log-in code and password. A physician had to log-in once, and was then able to continue registering their clients one after another. Moreover, when starting the system, physicians are given two options: to register a new client or to edit data of an existing client (see Fig. 3). For the latter, an overview was generated of all clients that had previously been registered by that specific nursing home. Clients of other nursing homes are not shown.

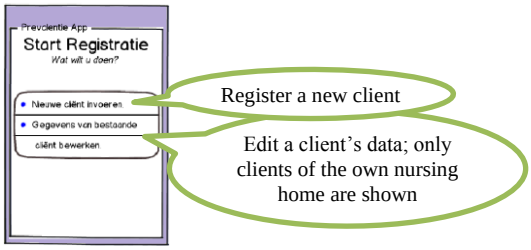

Figure 3. Example of a screen that leads to Tailored information

2) Dialogue Support

The prototype registration system requires physicians to indicate which pathogens caused an infection. However, during the user tests it became clear that within nursing homes, little funding is available to perform the laboratory tests to acquire this knowledge. Furthermore, if a laboratory test was performed at the moment of registration, its results were not always known yet. Therefore, in the final registration system, questions are added to ask whether a laboratory test was performed and whether its results were already known. If the latter question was answered with 'no' a pop-up screen appeared. This screen *reminded* [13] the physician that lab results should be added later.

Also, *suggestion* [13] is added to the final registration system. One example of the application of suggestion was used since physicians have to register all antibiotics that are used by their clients. However, the variety of antibiotics that exist is enormous and their names are complex. Initially, the intention was to let physicians scroll through an alphabetical list of all antibiotics (see Fig. 4).

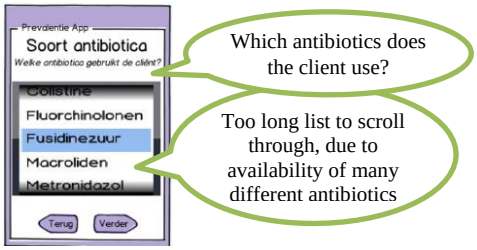

Figure 4. Example of the screen that subscribes the need for Suggestion

However, this was still too time consuming. Therefore, in the final registration system, a search system in which the physician enters the first three letters of the antibiotic is added. The system then automatically generates only antibiotics that start with these letters.

3) System Credibility Support

Finally, in healthcare in general and for the registration of healthcare-associated infections in nursing homes specifically, it is of great importance that the system is credible according to its users. Therefore, a website was created about the services provided by the registration system [15]. The Infection Manager website was developed

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for the EurSafety Health-net project [16]. This is a large and successful European project involving many hospitals, microbiology laboratories and other healthcare institutions. The part of the website about the registration system consists of e.g. background information about the project and the parties that were involved in the development process. This was intended to give more clarity about the *trustworthiness* and *expertise* of the project and its project members [13].

Finally, in the final registration system, it was decided to add the EurSafety logo, to give the system more *surface credibility* [13].

D. Analysis of the User-Friendliness of the Prototype

Based on the scenario-tests, many major and minor adjustments had to be made in the mock ups. These concerned the clarity of wording, sequence of questions, completeness, user-friendliness, design and location of the buttons. For example, initially, there were two screens in our prototype for 'Aids', which asks whether the client uses any aids such as a catheter or tracheotomy; and 'Incontinence', which asks whether the client is incontinent. During the user-tests, the subjects had several comments about these screens. First of all, whereas we interpreted the term 'aid' as being a catheter of some kind, the subjects indicated that the term 'aid' to them meant 'walker' (see Quote 2). So, they suggested using a different term.

> (Quote 2 – Originally in Dutch) "Yes, we use the word 'Aid' for something completely different. We use this word for walkers. So I would try to come up with a different word here."

Furthermore, they found the screen about incontinence strange. In one of the scenarios, a client was described who had a catheter. The participants indicated that although incontinence is a possible reason for clients to get a catheter, they did not consider this client as being incontinent anymore (see Quote 3). They, therefore, said the option of having a catheter or stoma should be added to this screen.

> (Quote 3 – Originally in Dutch) "You see, this client is not incontinent, but has a urethra catheter… So this is strange. You should add catheter here I guess. Because with a catheter you are not really incontinent anymore."

As a result, the two screens where replaced by a new screen. This screen asks whether a client is incontinent. However, an additional answer option has been added, to indicate that a client has a catheter or stoma.

After the fourth user-test, no major issues where found anymore. Therefore, meetings with Information and Communication Technology (ICT) developers were held to further discuss the requirements for the registration system and to finally develop it.

IV. DISCUSSION

This study was aimed at determining whether user-centered and persuasive design could support a faster, easier, more fitting, more reliable and clearer registration of healthcare-associated infections by elderly care physicians. Regarding the design process, it can be said that the holistic approach using the CeHRes roadmap has provided the opportunity to not only develop an eHealth technology that fits the needs of its users and is successful in what it is intended to do, but to also make sure that it fits its context.

The constant and structural cooperation with end-users during the development process, gave us the opportunity to make it an iterative process. This means that it was possible to evaluate the eHealth technology in every stage of its development, and to (at any time) adjust the direction that it was going in. This aids in the development of an eHealth technology that fits its users' needs and context, and could potentially prevent high costs of re-design if major necessary adjustments are only found after final release of the technology.

Certainly, we still want to evaluate the speed, user-friendliness, fit with work processes, ease of use, clarity and persuasiveness of the final registration system. Thus, a summative evaluation is currently being planned. This evaluation will combine both qualitative and quantitative methods and will e.g. focus on user friendliness, speed of registration (both were found important by the end-users) and amount of errors that are made (important for the quality of the data). But for now, it can be said that the new system has already been used in two rounds of prevalence measurements, successfully registering over 3000 nursing home residents. It is web-based, and can therefore be used on any device capable of connecting to the world wide web. An example of a screen of the eventual registration system is given in Fig. 5.

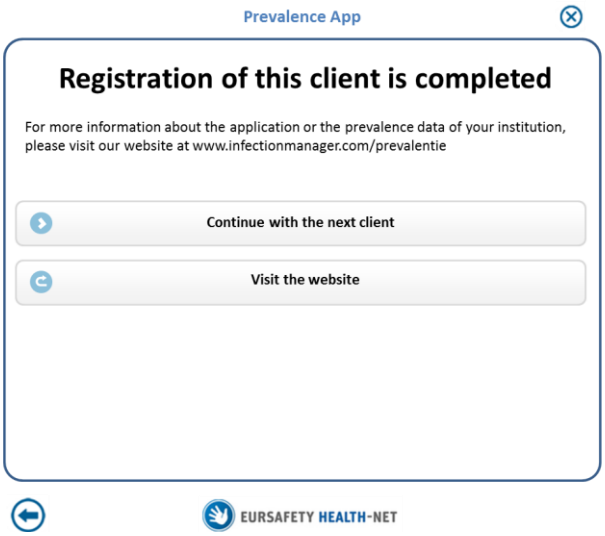

Figure 5. Example of the look and feel of the eventual registration system (Originally in Dutch)

A. Limitations

A limitation of this study is that it suffered from very strict and ambitious deadlines. This limited us in the amount of effort that we could put into the implementation stage of the development. Although this is thought to be a very relevant stage according to the CeHRes Roadmap, in this project its influence might be limited. The elderly care physicians who are the end-users of the registration system in this study, are obligated to use it if their nursing home participates in the prevalence measurements.

Another possible limitation might be that our study had a relatively low number of participants. However, aim of this study was solely the development of an eHealth technology, not to perform an evaluation of its effects.

Also, this project concerned an already existing intervention. Question was, whether technology can aid in its optimization. The context was, however, explored: regulations and conditions for use of the technology and the fit with existing systems for processing the data have been studied in this project.

Finally, the given setting for this project (nursing homes) presented us with its very own challenges. The opportunities for using technology were limited, because of the technological infrastructure of Dutch nursing homes (wherein often outdated PCs are used), and the degree to which people are used to working with technology (e.g. only 47,1% of the physicians used a smartphone). However, this gave us an interesting opportunity to put ourselves and the possibilities of the CeHRes Roadmap to the test, to see how it and how we would cope with such limitations.

V. CONCLUSION

This article goes beyond the mere development of eHealth technologies. It has subscribed our strong believe that involving end-users in all stages of development is of paramount importance for the creation of successful eHealth technologies, because (1) it gives insight in the needs and wishes of the end-users, that have to be met by the eHealth technology; (2) end-users are able to give feedback on both details (the location of a button) and on the bigger picture (the clinical practice that the technology has to be used in); (3) it allows for the development to be an iterative process, which may prevent costly redesign to be necessary; and (4) although they might have used their own words to express themselves, end-users appeared to have very clear ideas about the their needs regarding Persuasive Systems Design.

ACKNOWLEDGMENT

This project was funded by the Interreg IV “EurSafety Health-net” project. We also thank the elderly care physicians who participated in this study.

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Fuzzified Clustering and Point Set Continuous Approximation in Prognosticating Gastric Cancer Surgery

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Abstract— **We discuss two computational techniques in the current paper. In the first part, we aim at employing FCM (fuzzy c-means) clustering to compute membership degrees of two clusters providing decisions to perform surgery or not for a testing set of 25 gastric cancer patients. The second part handles mathematical modelling of a common function approximating the information obtained from the c-means procedure. After constructing the equation of the function, we can make the decision about the surgery in the form of the surgery degree for an arbitrary gastric cancer patient. A centre, dealing with mathematical techniques concerning surgery prognoses, can quickly decide about surgery for the patient who lives in a remote place. A transmission of information among the centre and some hospitals, interested in adopting the centre services, can facilitate surgery decision-making. This trial can be treated as a contribution in the telemedicine domain.**

Keywords–c-means clustering; surgery degrees; clinical characteristic value; weights of importance; truncated π-functions.

I. INTRODUCTION

Multidisciplinary cancer conferences play a very important role in decision-making process in modern treatment of gastric cancer patients. The aim of the conference is to establish assessments and treatment decisions for particular patients. The most discussed method of gastric cancer treatment is the partial or the total resection of the stomach, which makes the surgery decision so important.

To support the surgery decision-making, we develop different mathematical models, in which the entry data consist of the values of clinical markers, sampled during the examinations of the patients.

We have been provided with the clinical data of 25 gastric cancer patients, randomly selected and treated as a testing set. When designing the mathematical apparatus, we first intend to adapt the c-means method, separating patients in two sets named "degree of surgery" and "degree of no surgery". A multidimensional data point-vector, consisted of values of the decisive biological markers, is assigned to each patient. The patient's age, the *crp*-value (the C reactive proteins value) [1] and the body weight play a significant role in the surgery diagnosis.

The differentiation of patients-vectors in two classes is well done by putting forward the fuzzified version of cluster analysis [2]. Among clustering approaches, the fuzzy c-means clustering is regarded as the most efficient [2][3][4]. The earlier trials, involving fuzzy c-means clustering in surgery decision-making, were discussed by us in [5][6].

For each tested patient, the cluster matrix will deliver degrees of surgery and degrees of no surgery belonging to interval [0, 1].

After running the c-means algorithm, some characteristic values will be assigned to all patients tested. The characteristic values will combine measurements of biological markers with importance weights of these markers. Further, we will determine a set of points containing pairs (patient characteristics, degree of surgery). After inserting the points into the two-dimensional coordinate system, in accordance with ascending order of patient characteristic values, we will make a trial of approximating this set of points by the truncated version of the π-function [7][8]. The equation of the truncated π function makes possible to evaluate the surgery degree for an arbitrary patient. The approximation of the point set and prognoses, made for casual gastric cancer patients, constitute the paper's second part, where our earlier and new theoretical contributions are sampled.

We cannot compare our results with other mathematical trials testing the operation decisions, since we have not found any traces of such trials in literature. A confrontation of our results with the physicians' decisions is the only way to validate a proposed mathematical system.

Our further intention is to implement centralized computer programs. By spreading the effects of the program actions, we count on awaking some interest in other centres. These are expected to communicate with the main transmission station in order to obtain the support in surgery decision making. This trial of starting the communication by computers in the matter of surgery decision can be regarded as a contribution in the telemedicine domain.

In Section II we list the steps of fuzzy c-means clustering. The technique of generating entries in the initial matrix is discussed in Section III. Section IV provides us with surgery prognoses made for 25 patients tested. Characteristic values of patients are introduced in Section V.

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The values will be later involved in the procedure of approximation of points (characteristics of patient, degree of surgery) by a continuous function in Section VI. We conclude in Section VII.

II. FUZZY C-MEANS CLUSTERING ALGORITHM

Let us recall the definition of a fuzzy set. The fuzzy set A is a collection $A = \{(x, y = \mu_A(x))\}, x \in A, \mu_A(x) \in [0,1]$. Each element x gets a membership degree $\mu_A(x)$, determined by the membership function μ_A.

Suppose that $X = \{x_1, \dots, x_n\}$ is a finite data set. Each data point $x_k = \left(x_{k_1}, \dots, x_{k_p}\right), k = 1, \dots, n,$ is a pattern vector in R^p. Fuzzy c-means algorithm partitions X in a collection of S_i subsets, $2 \le i \le c$, called fuzzy clusters. By running the algorithm repeatedly, a list of v_i cluster centres and a partition matrix U are returned.

The description of the c-means algorithm is performed in the following steps [2]:

1) Select c=2, initialize m=3 and the termination tolerance $\epsilon = 10^{-8}$.

2) Set $l = 0$.

3) Determine the initial values of degrees in partition matrix U^l.

4) Calculate cluster centres $v_i^l, i = 1, \dots, c$, as

$$v_i^l = \frac{\Sigma_{k=1}^{n}\left(\left(\mu_{ik}^l\right)^m \cdot x_k\right)}{\Sigma_{k=1}^{n}\left(\mu_{ik}^l\right)^m}. \quad (1)$$

5) Calculate the updated partition matrix U^{l+1} by

$$\mu_{ik}^{l+1} = \frac{\left(\frac{1}{d\left(x_k, v_i^l\right)}\right)^{1/m-1}}{\Sigma_{j=1}^{c}\left(\frac{1}{d\left(x_k, v_j^l\right)}\right)^{1/m-1}}. \quad (2)$$

6) If $\|U^{l+1} - U^l\| \ge \epsilon$, then set $l = l + 1$, and go to step 4. If $\|U^{l+1} - U^l\| \le \epsilon$, then stop the procedure. Matrix U^{l+1} is the optimal distribution of membership degrees of x_k in clusters S_i. The symbol $\| \|$ denotes a matrix norm.

The steps of the c-means algorithm [2] contain expressions, which are explained in turn as: n is a number of data points, c is a number of clusters, the value of $\mu_{S_i}(x_k)$ stands for the membership degree of x_k in cluster S_i, $d(v_i, x_k)$ indicates the Euclidean distance between the cluster centre v_i and x_k, and constant $m > 1$ is a weighting exponent.

The Euclidean distance is proved to guarantee a fast convergence of the algorithm to final results. We state $m = 3$ as the curves, approximating clusters, are smoothest.

The prior determination of the membership degrees in U^0 plays a crucial role in the c-means algorithm, as their choice not only can affect the convergence speed, but also may have a direct impact on the results of the classification [2][9]. To avoid inaccuracy in final results, we will discuss our own technique of calculation of degrees in U^0 to avoid guessing at their values intuitively.

III. DEGREES IN THE INITIAL PARTITION MATRIX

To make appropriate evaluations of the membership of x_k in S_i, we adopt the s-class function [10]

$$s(z, \alpha, \beta, \gamma) = \begin{cases} 0 & \text{for} \quad z \le \alpha, \\ 2\left(\frac{z-\alpha}{\gamma-\alpha}\right)^2 & \text{for} \quad \alpha \le z \le \beta, \\ 1 - 2\left(\frac{z-\gamma}{\gamma-\alpha}\right)^2 & \text{for} \quad \beta \le z \le \gamma, \\ 1 & \text{for} \quad z \ge \gamma. \end{cases} \quad (3)$$

in further calculations.

Surgery prognoses usually can be expressed by "degree of surgery" contra "degree of no surgery", when basing on the age, the *crp*-values and the weight. The linguistic degrees of surgery, like, e.g., "little" or "large", can be proposed by a physician as terms of a list L.

Generally, let us suppose that $L = \{L_1, \dots, L_\omega\}$ is a linguistic list consisting of ω words, where ω is an odd integer. Each word is associated with a fuzzy set, also named L_s, s = 1,...,ω. Furthermore, let E be the length of a common reference set R, containing all fuzzy sets L_s. Let $z \in R$. For instance, R can be recognized as a density set between 0 and 100, in which densities about z = 20 belong to "little". We divide the linguistic terms into three groups named: a left group, a middle group and a right group.

The membership functions, assigned to the leftmost terms, are parametric functions, which are yielded by (4) as [11][12]

$$\mu_{L_t}(z) = \begin{cases} 1 \text{ for } z \le \frac{E(\omega-1)}{2(\omega+1)}\delta(t), \\ 1 - 2\left(\frac{z - \frac{E(\omega-1)}{2(\omega+1)}\delta(t)}{\frac{E(\omega-1)}{\omega(\omega+1)}\delta(t)}\right)^2 \\ \text{for } \frac{E(\omega-1)}{2(\omega+1)}\delta(t) \le z \le \frac{E(\omega-1)}{2\omega}\delta(t), \\ 2\left(\frac{z - \frac{E(\omega-1)(\omega+2)}{2\omega(\omega+1)}\delta(t)}{\frac{E(\omega-1)}{\omega(\omega+1)}\delta(t)}\right)^2 \\ \text{for } \frac{E(\omega-1)}{2\omega}\delta(t) \le z \le \frac{E(\omega-1)(\omega+2)}{2\omega(\omega+1)}\delta(t), \\ 0 \text{ for } z \ge \frac{E(\omega-1)(\omega+2)}{2\omega(\omega+1)}\delta(t), \end{cases} \quad (4)$$

where $\delta(t) = \frac{2t}{\omega-1}, t = 1, \dots, \frac{\omega-1}{2}$ is a parametric function, depending on left function number t.

The membership function in the middle has the form of a bell. It is designed by (5) in the form of [11][12]

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$$\mu_{L_{\frac{\omega+1}{2}}}(z)=\begin{cases}0 & \text{for } z\le\frac{E(\omega-2)}{2\omega},\\ 2\left(\frac{z-\frac{E(\omega-2)}{2\omega}}{\frac{E}{\omega}}\right)^2 & \text{for } \frac{E(\omega-2)}{2\omega}\le z\le\frac{E(\omega-1)}{2\omega},\\ 1-2\left(\frac{z-\frac{E}{2}}{\frac{E}{\omega}}\right)^2 & \text{for } \frac{E(\omega-1)}{2\omega}\le z\le\frac{E}{2},\\ 1-2\left(\frac{z-\frac{E}{2}}{\frac{E}{\omega}}\right)^2 & \text{for } \frac{E}{2}\le z\le\frac{E(\omega+1)}{2\omega},\\ 2\left(\frac{z-\frac{E(\omega+2)}{2\omega}}{\frac{E}{\omega}}\right)^2 & \text{for } \frac{E(\omega+1)}{2\omega}\le z\le\frac{E(\omega+2)}{2\omega},\\ 0 & \text{for } z\ge\frac{E(\omega+2)}{2\omega}.\end{cases} \quad (5)$$

Finally, the membership functions on the right-hand side are expressed by (6) as

$$\mu_{L_{\frac{\omega+3}{2}+t-1}}(z)$$
$$=\begin{cases}0 \text{ for } z\le E-\frac{E(\omega-1)(\omega+2)}{2\omega(\omega+1)}\varepsilon(t),\\ 2\left(\frac{z-\left(E-\frac{E(\omega-1)(\omega+2)}{2\omega(\omega+1)}\varepsilon(t)\right)}{\frac{E(\omega-1)}{\omega(\omega+1)}\varepsilon(t)}\right)^2\\ \text{for } E-\frac{E(\omega-1)(\omega+2)}{2\omega(\omega+1)}\varepsilon(t)\le z\le E-\frac{E(\omega-1)}{2\omega}\varepsilon(t),\\ 1-2\left(\frac{z-\left(E-\frac{E(\omega-1)}{2(\omega+1)}\varepsilon(t)\right)}{\frac{E(\omega-1)}{\omega(\omega+1)}\varepsilon(t)}\right)^2\\ \text{for } E-\frac{E(\omega-1)}{2\omega}\varepsilon(t)\le z\le E-\frac{E(\omega-1)}{2(\omega+1)}\varepsilon(t),\\ 1 \text{ for } z\ge E-\frac{E(\omega-1)}{2(\omega+1)}\varepsilon(t).\end{cases} \quad (6)$$

A new function $\varepsilon(t)=1-\frac{2(t-1)}{\omega-1}, t=1,\dots,\frac{\omega-1}{2}$ allows generating all rightmost functions one by one, when setting *t*-values in (6).

IV. THE SURGERY DECISION FOR 25 PATIENTS

To make a decision about surgery, concerning an individual patient in accordance with his/her biological markers' values, we must involve the medical experience in the decisive process. In order to facilitate a conversation with a physician, we have prepared a list named "The primary medical linguistic judgment of surgery grade"= L = $\{L_1=$ "none", $L_2=$ "little", $L_3=$ "medium", $L_4=$ "large", $L_5=$ "total"$\}$. The evaluation of no surgery will be an inverted surgery term with respect to L.

The excerpt of the data set, shown in TABLE I, consists of the patients' clinical records and primary linguistic estimations of surgery grades. The judgments are made by the medical expert. The total medical report contains 25 gastric cancer patients, randomly selected.

TABLE I. THE DATA SET OF 25 GASTRIC CANCER PATIENTS

Patient x_k	Attribute-vectors and surgery judgments		
	Attribute-vectors (Age, weight, crp)	*Surgery cluster S_1*	*No Surgery cluster S_2*
x_1	(71, 85, 1)	Total	None
x_2	(81, 70, 9)	Medium	Medium
…	…	…	…
x_{25}	(54, 49, 36)	None	Total

Each verbal expression, being the term of L, is associated with a fuzzy set. L_1 and L_2 represent two left fuzzy sets. L_3 is the fuzzy set in the middle, whereas L_4 and L_5 constitute two rightmost fuzzy sets. Unfortunately, these linguistic items do not provide us with any information about degrees, expected in matrix U^0. To estimate degrees of surgery in cluster S_1 and degrees of no surgery in cluster S_2, we have initiated the following enumeration technique.

By employing (4), (5) and (6) for E = 100 (a typical reference set in medical investigations of densities) and ω = 5, we derive the membership functions of L_s, s = 1,…,5. Functions L_s are sketched in Figure 1.

After setting $\alpha=0, \beta=50$ and $\gamma=100$ in a new *s*-function, impacted over set R, we determine

$$\mu_R(z) = s(z,0{,}50{,}100), \quad (7)$$

whose graph is added to Figure 1.

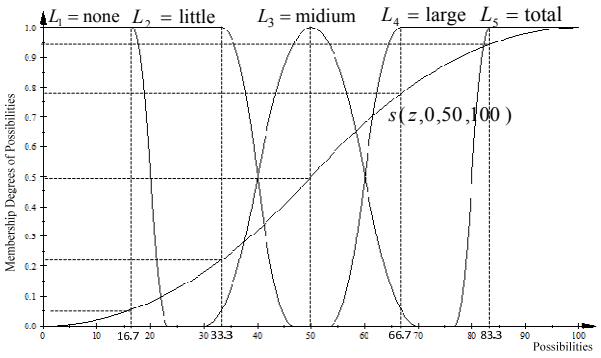

Figure 1. The collection of membership functions generated by (4), (5), (6) and (7)

Figure 1 helps us to evaluate the degrees taking place in the first partition matrix U^0. The second coordinates of the intersection points between $\mu_R(z)$ and $\mu_{L_s}(z)$, s = 1,…,5, will substitute the linguistic structures, filling L. Therefore, 0.056 is assigned to "none", 0.22 to "little", 0.5 to "medium", 0.78 to "large" and 0.944 to "total". The list L can be extended by adding other verbal expressions to it.

After the arrangements of numerical compensations of the terms from L, the words in TABLE I are replaced by values put in TABLE II.

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TABLE II. DATA SET WITH INITIAL DEGREES

Patient x_k	Attribute-vectors and surgery degrees		
	Attribute-vectors (Age, weight, crp)	$\mu_{S_1}(x_k)$	$\mu_{S_2}(x_k)$
x_1	(71, 85, 1)	0.944	0.056
x_2	(81, 70, 9)	0.5	0.5
...	...	...	...
x_{25}	(54, 49, 36)	0.056	0.944

The entries of the initial partition matrix $U^0_{2\times 25}$ contain the values coming from the last two columns in TABLE II.

If we go back to the c-means clustering algorithm and involve Matlab in calculations, then the cluster centres will become stable after 31 iterations.

The last partition matrix has a pattern

$$U^{31} = \begin{matrix} & x_1 & \cdots & x_{25} \\ S_1 & 0.79 & \cdots & 0.31 \\ S_2 & 0.21 & \ldots & 0.69 \end{matrix}_{2x25}.$$

The relations referring to magnitudes of the final degrees for 25 patients, classified for surgery in S_1 and for no surgery in S_2, have confirmed the primary hypotheses. The final verdicts are softer, e.g., "total" is reduced to "large" for surgery prognosis, whereas "none" gets a status of "little" for no surgery.

V. PATIENT CHARACTERISTIC VALUES

We now generate a set of points $(x_k,\ \mu_{S_1}(x_k)), k = 1, \ldots, n$. Let us note that the first coordinates x_k do not belong to any real-valued x_k-axis, since x_k have not been characterized by any quantity. We thus want to assign a characteristic value to each patient x_k [12] to be able to place x_k's characteristic values in an ascending order.

The patients' *crp*-values, the ages and the body weights play a significant role in the surgery diagnosis. Let us denote the space of the *crp*-values by CRP = [0, 85], the space of ages by A = [0, 100] and express the body weight space by BW = [40, 120].

For x_k, a characteristic value $f_{x_k}(crp^c\ a^c\ bw^c) = w_{crp}crp^c + w_a a^c + w_{bw} bw^c$, $a^c \in A$, $crp^c \in CRP$ and $bw^c \in BW$, k = 1,...,n, [12]. The multipliers w_{crp}, w_a and w_{bw} are the importance weights, emphasizing the decisive power of each biological parameter for the surgery decision.

To find values of importance weights w_{crp}, w_a and w_{bw}, we present our own procedure, sketched below.

Generally, we compare p parameters to assign importance weights to them. A sequence $p_1 > p_2 > ... > p_p$ will be thus arranged due to the expert's opinion, provided that ">" is interpreted as "more important than". We wish the sum of all weights w_q, q = 1,...,p, to be 1 in accordance with

$$p \cdot r + (p-1) \cdot r + \cdots + 2 \cdot r + 1 \cdot r = 1 \qquad (8)$$

where r is a quotient depending on p. Hence, $w_q = (p - q + 1) \cdot r$, for q = 1,...,p.

In the gastric cancer example, the physician determines the sequence *crp*>age>weight, which lets us evaluate $w_{crp} = 0.498$, $w_a = 0.333$ and w_{bw} =0.166.

Example 1

The eighty-one year old man x_k, weighing 90 kg and revealing *crp*=16, is given by $f_{x_k}(crp^c\ a^c\ bw^c) = 49.88$.

VI. THE CURVE FITTING FOR THE POINT SETS

We wish to find a curve, which approximates the set of pairs $(f_{x_k}(crp^c\ a^c\ bw^c), \mu_{S_1}^{U^{31}}(x_k))$, symbolically denoted by $\left(f_{x_k}, \mu(x_k)\right)$. In the set, the pairs are arranged in ascending order of characteristic values f_{x_k}.

In accordance with [7][8] (our earlier procedures), we utilize the equation of the truncated π function in the process of approximation of point sets, which build the pattern of a bell. The classical π-function is limited by $s(z,\alpha_1,\beta_1,\gamma_1{=}\alpha_2)$ in the left part and $1{-}s(z,\alpha_2{=}\gamma_1,\beta_2,\gamma_2)$ in the right part, respectively [10]. Its truncated version has no intersection points with the z-axis. Without discussing the details, which are available in [7][8], we only mention that we need three characteristic points to start with the approximation. When remembering that $f_{x_k}, k = 1, \ldots, n$, are ordered in the ascending sequence, we select:
($f_1{=}\min_{k=1,\ldots,n}(f_{x_k})$, μ_1), (f_2, $\mu_2{=}\max_{k=1,\ldots,n}(\mu(x_k))$) and ($f_3{=}\max_{k=1,\ldots,n}(f_{x_k})$, μ_3).

The coordinates of the points are included into four general equations of the truncated π:

a)

$$\pi_{left\ slope}(f_{x_k}) = \mu_{"surgery"}(f_{x_k}) = \begin{cases} 0 & \text{for} \quad f_{x_k} < f_1, \\ 2\mu_2\left(\frac{f_{x_k}-\alpha}{f_2-\alpha}\right)^2 & \text{for} \quad f_1 \le f_{x_k} \le \beta_1, \\ \mu_2\left(1-2\left(\frac{f_{x_k}-f_2}{f_2-\alpha}\right)^2\right) & \text{for} \quad \beta_1 \le f_{x_k} \le f_2, \end{cases} \qquad (9)$$

for $\alpha = \frac{f_1 - f_2\sqrt{\frac{\mu_1}{2\mu_2}}}{1-\sqrt{\frac{\mu_1}{2\mu_2}}}$, $\mu_1 < \frac{\mu_2}{2}$ and $\beta_1 = \frac{\alpha+f_2}{2}$,

b)

$$\pi_{left\ slope}(f_{x_k}) = \mu_{"surgery"}(f_{x_k}) = \begin{cases} 0 & \text{for} \quad f_{x_k} < f_1, \\ \mu_2\left(1-2\left(\frac{f_{x_k}-f_2}{f_2-\alpha}\right)^2\right) & \text{for} \quad f_1 \le f_{x_k} \le f_2, \end{cases} \qquad (10)$$

where $\alpha = f_2 - \frac{f_2 - f_1}{\sqrt{\frac{\mu_2-\mu_1}{2\cdot\mu_2}}}$ for $\mu_1 \ge \frac{\mu_2}{2}$.

c)

$$\pi_{right\ slope}(f_{x_k}) = \mu_{"surgery"}(f_{x_k}) = \begin{cases} \mu_2\left(1-2\left(\frac{f_{x_k}-f_2}{\gamma-f_2}\right)^2\right) & \text{for} \quad f_2 \le f_{x_k} < \beta_2, \\ 2\mu_2\left(\frac{f_{x_k}-\gamma}{\gamma-f_2}\right)^2 & \text{for} \quad \beta_2 \le f_{x_k} \le f_3, \\ 0 & \text{for} \quad f_{x_k} > f_3, \end{cases} \tag{11}$$

for $\gamma = \frac{f_3 - f_2\sqrt{\frac{\mu_3}{2\cdot\mu_2}}}{1-\sqrt{\frac{\mu_3}{2\cdot\mu_2}}}$, when $\mu_3 < \frac{\mu_2}{2}$ and $\beta_2 = \frac{f_2+\gamma}{2}$

and

d)

$$\pi_{right\ slope}(f_{x_k}) = \mu_{"surgery"}(f_{x_k}) = \begin{cases} \mu_2\left(1-2\left(\frac{f_{x_k}-f_2}{\gamma-f_2}\right)^2\right) & \text{for} \quad f_2 \le f_{x_k} < f_3, \\ 0 & \text{for} \quad f_{x_k} > f_3, \end{cases} \tag{12}$$

in which $\gamma = f_2 + \frac{f_3 - f_2}{\sqrt{\frac{\mu_2-\mu_3}{2\mu_2}}}$ for $\mu_3 \ge \frac{\mu_2}{2}$.

Example 2

The data of 25 patients x_k, k = 1,...,25, are rearranged in ascending order due to $f_{x_k}(crp^c\ a^c\ bw^c) = 0.498crp^c + 0.333a^c + 0.166bw^c$. For $(f_{x_k}(crp^c\ a^c\ bw^c), \mu_{S_1}^{U31}(x_k))$, we select ($f_1$, μ_1) = (32.23, 0.682), (f_2, μ_2) = (36.428, 0.824) and (f_3, μ_3) = (112.60, 0.374). Figure 2 plots all points, assisting the patients' clinical data and surgery degrees.

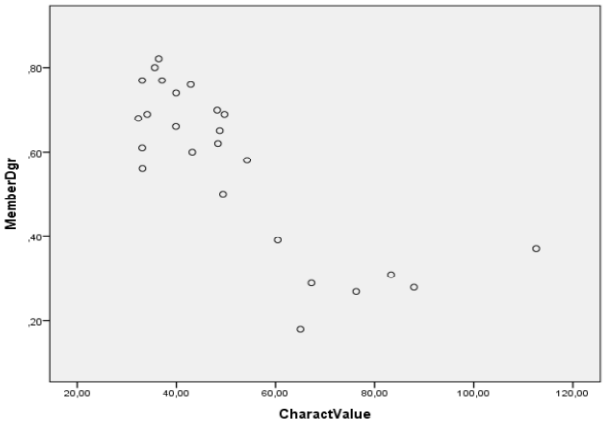

Figure 2. The set of points $(f_{x_k}(crp^c\ a^c\ bw^c), \mu_{S_1}^{U31}(x_k)), k = 1, \ldots, 25$

The left part of the truncated π, when $\mu_1 > \frac{\mu_2}{2}$ (0.682>0.412), has the equation

$$\pi_{left\ slope}(f_{x_k}) = \mu_{"surgery"}(f_{x_k}) = \begin{cases} 0 & \text{for } f_{x_k} < 32.23, \\ 0.824\left(1-2\left(\frac{f_{x_k}-36.428}{36.428-22.127}\right)^2\right) & \text{for } 32.23 \le f_{x_k} \le 36.428, \end{cases}$$

for restored $\alpha = 36.428 - \frac{36.428-32.23}{\sqrt{\frac{0.824-0.682}{2\cdot 0.824}}} = 22.127$, due to b).

To derive the right part of π, we study c), as $\mu_2 < \frac{\mu_3}{2}$. Equation (11) provides us with the formula

$$\mu_{"right\ slope"}(f_{x_k}) = \mu_{"surgery"}(f_{x_k}) = \begin{cases} 0.824\left(1-2\left(\frac{f_{x_k}-36.428}{181.9-36.428}\right)^2\right) & \text{for } 36.428 \le f_{x_k} < 109.164, \\ 0.824\left(2\left(\frac{f_{x_k}-181.9}{181.9-36.428}\right)^2\right) & \text{for } 109,164 \le f_{x_k} \le 112.6, \\ 0 & \text{for } f_{x_k} > 112.6, \end{cases}$$

where γ = 181.9.

The graph of both branches of $\mu_{"surgery"}(f_{x_k})$ is drawn in Figure 3. The function, created for degrees of no surgery, has a formula $1 - \mu_{"surgery"}(f_{x_k})$.

The formulas, expressed in Example 2, allow making surgery prognoses for an arbitrary patient, whose characteristic value lies in interval [32.23, 112.6]. If we face more extreme quantities, then we should construct another partition matrix, adapted to a new collection of clinical data.

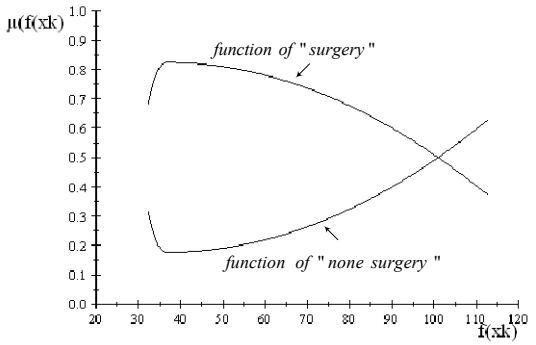

Figure 3. The membership functions of "surgery" and "none surgery"

Example 3

Evaluate a degree of surgery for the patient from Example 1. The patient characteristic value has equalled 49.88. Hence, $\mu_{"surgery"}(49.88) = 0.824\left(1-2\left(\frac{49.88-36.428}{181.9-36.428}\right)^2\right) = 0.809$.

VII. CONCLUSION AND FUTURE WORK

We have applied fuzzy 2-means clustering analysis to partition a patient data set, containing clinical records of 25

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gastric cancer patients, in two fuzzy clusters. These reveal the numerical decision of states: "surgery" and "no surgery".

We notice that the patients' original clinical marker values lead to higher membership degrees in the initial partition matrix, when comparing them to the lower values in the final matrix. This phenomenon can be explained by the fact that the decision for an individual patient has been made by the assistance of all data filling the data set. This means that the medical knowledge provided in the form of the collective information, reset numerically, could decide "softer" decisions. The obtained results converge to the surgery judgments made by physicians from Blekinge County Hospital, Karlskrona, Sweden.

In the second part of the study, we have started with the constructions of characteristic values. The values are mixtures of clinical measurements and importance weights of markers examined. Then the points, characterized by coordinates equal to the patient characteristics and degrees of surgery, have been surrounded by the curve. The equation of this curve may be used to prognosticate a degree of surgery for any gastric cancer patient. The approximation by the truncated π cumulates a little error for point shapes, similar to parts of a bell. The placement of minimal and maximal degrees in the graph of the curve, connected to "degree of surgery", agrees with the medical knowledge on recommendations of surgery in the cases of gastric cancer patients.

The idea of applying fuzzy set theory to the surgery decision is a pioneer in the field of medical applications of mathematics. Therefore, we cannot compare our effects to similar contributions, made in this domain. In spite of that, the physicians, cooperating with us, have confirmed the reliability of mathematical models.

Apart from applications of ready-made algorithms, like the c-means method, we have introduced our own earlier and newer mathematical models to this medical example. The membership function families, exploiting to determine the initial membership degrees in the partition matrix, have been an efficient tool in the algorithm. The functions, furnished with parameters, allow constructing arbitrary linguistic lists containing many verbal judgments. The weights of importance have been computed by the action of a simple algorithm, specially constructed for this purpose. Lastly, the procedure of approximation of point sets, resembling the shape of a bell, remains our own substantial contribution. Without the equation of the approximating curve, we could not make any surgery prognoses for casual patients, who do not exist in the testing set of patients.

Future challenges are also planned. We want to test larger samples of patients to open a database of truncated π equations, covering the most cases of patient clinical data. This may give us a chance to establish the information computer centre, making surgery prognoses.

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Reduced Elective Surgery Cancellations Through Patient Involvement In Pre-Operative Planning In Norway

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***Abstract*—Surgery cancellations are undesirable in hospital settings as they increase costs, reduce productivity and efficiency, increase waiting lists, and directly affect the patient. The elective surgery cancellations problem in a North Norwegian University Hospital is addressed. Based on observations and interviews, conducted at the hospital, lack of information during the pre-operative planning was identified as the main cause of elective surgery cancellations. The problems with the existing pre-operative process were identified and a new process is proposed. By studying the pre-operative planning at the hospital, we have determined that part of the information flow can be moved to the patient at home. From the work presented herein, we conclude that the assessment information required during the pre-operative planning can be compiled in a personal health assessment questionnaire, and requested from the patient, at an earlier stage.**

Keywords-elective surgery cancellations; pre-operative planning; communication; process optimization; Norway

I. INTRODUCTION

Surgical departments are simultaneously the major source of investment, and the greatest source of revenue for most hospitals [1, 2]. However, it is known that between 10 and 40 % of elective surgeries are cancelled [1, 3-5]. In western countries, up to 20 % of elective surgeries are cancelled on the day of surgery [6-8]. Furthermore, it has been reported that 50 % of these cancellations might be avoided [1, 9, 10].

Surgery cancellations are undesirable in hospital settings as they increase costs, reduce productivity and efficiency, increase waiting lists, and directly affect the patient [3, 8, 11]. Considerable resources are invested in maintaining operating theatres, and having surgeons and theatre staff available on an agreed schedule [1, 12]. In spite of this, the cancellation rate of elective surgeries is high, especially in the public sector [9, 13]. Cancellations can significantly inconvenience patients and their families [14, 15]. It is also reported that patients may suffer psychological stress, and/or financial hardships [9]. Accordingly, cancellations are stressful and costly, with a high level of emotional involvement before surgery [1].

The causes for elective surgery cancellation are diverse and may be divided in two major categories: (a) hospital, and (b) patient related reasons, when considering who took the underlying decision to cancel. Hospital related reasons are the most frequent and encompass causes such as the unavailability of the surgical team [3, 7, 8], incomplete pre-operative study/preparation [7, 16], lack of surgical/anesthetic readiness [7, 8], and lack of theatre time due to extended duration of scheduled surgeries [7]. On the other hand, patient related causes are mostly due to patient no-shows and refusal to undergo surgery [7, 8, 16]. It is argued that the majority of cancellations are due to information that existed prior to the day of surgery, but was not available when required [9, 13, 17-20].

In line with what is reported in literature, our site of research, the University Hospital of North Norway (UNN), has identified inadequate planning due to lack of information as a main cause for cancellations (Figure 1). The hospital has reported that more than 50 % of all cancellations at UNN are related to inadequate pre-operative planning [17]. It is anticipated that the pre-operative planning process may be improved if adequate patient information is gathered at an earlier stage, before the patient is admitted at the hospital.

In this paper, the elective surgery cancellation problem caused by inadequate pre-operative planning, in a University Hospital in Norway, is addressed. We started by mapping and evaluating the pre-operative process at UNN, and explored a system for gathering information from patients on his/her condition through a personal health assessment questionnaire.

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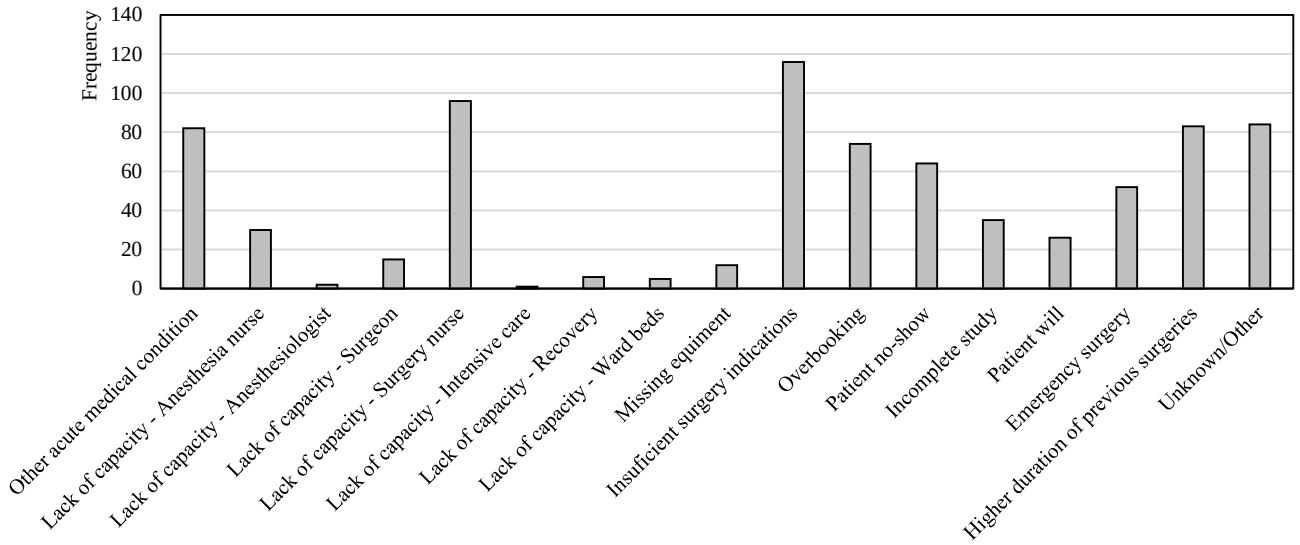

Figure 1. Causes for day of surgery cancellations distribution at UNN from January to June 2011.

This paper is divided in six sections. In the first section the problem object of the study is described and classified according to its causes. In the second section a brief review of the state of the art is presented. Data collection methodologies, with which the results were obtained, are presented and explained in the third section. The results are disclosed and interpreted in sections four and five. In the last section conclusions about the results are drawn, and some indicators of future work in the area foreseen.

II. BACKGROUND

Elective surgery cancellations, due to lacking information, at UNN are mainly related to inadequate pre-operative planning. In literature, pre-operative planning is reported to be approached in several different ways. A brief literature review on some of the approaches is presented below.

A widely studied approach to the elective surgery cancellation problem is the establishment of pre-operative assessment clinics (POACs). The aim of a POAC is to prepare patients for the administration of anesthesia and for surgery. The implementation of POACs may take different configurations relating to the worker leading the appointment. Doctor-led POACs were implemented by [16, 21-23] in an attempt to solve elective surgery cancellations due to lacking information. In this settings, patients are referred to the POAC either from the ward or the outpatient clinic. It was concluded that the number of cancellations was reduced but considered not significant [16]. In nurse-led POACs [24-26] the role of the physicians is transferred to the nurse. Thus, in such environments, the pre-operative assessment is undertaken by nurses, with overall supervision of a consultant anesthesiologist. Nurse-led pre-operative assessment systems POACs do not address the hypothesis that the pre-operative assessment information may be collected from the patient at home.

A different approach to improve pre-operative planning is to re-evaluate the role of health workers in the pre-operative process, and create tools that enable the transfer of responsibilities from physicians to nurses. It is advocated that the pre-operative assessment of elective surgical patients may be undertaken by trained nurses [18, 27, 28]. Following this hypothesis, nurse-led pre-operative assessment systems have been implemented [18, 27, 28], using protocols to guide nurses in the decision making process. Nurse-led pre-operative systems do not address the hypothesis that the pre-operative assessment information may be collected from the patient at home.

Searches on the major academic literature databases (e.g. PubMed, Web of Science, Inspec, SCOPUS), on pre-operative planning that use communication with the patient at home, did not retrieve any relevant result. Following, an approach to the problem of elective surgery cancellations by contacting the patient at home is presented.

Telephone calls are being studied as a solution to reduce elective surgery cancellations, due to patient no-shows, on the day-of-surgery [29, 30]. Such studies propose a communication channel between the patient and the provider to enable the confirmation of the patient's intention to attend surgery, or simply address patient questions and concerns. Information exchange between health personnel and patients, while the patients are still at home, may solve some of today's challenges with late pre-surgical planning and, consequently, cancellations of surgical procedures.

The aim of our research is to reduce the elective surgery cancellations at UNN, by studying pre-operative planning and determine if it may be moved from the hospital to the patient at home. We will explore if surgical patients and health personnel can collaborate in a team while the patient is still at home, and if this reduces elective surgery cancellations, by better preparing hospitals and patients for surgical procedures.

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III. MATERIALS AND METHODS

The management at UNN, our site of research, is determined to reduce the cancellation rate at the hospital. Resources have been allocated, and a Lean process for elective surgical patient pathways at the Operation and Intensive care clinic has been initiated at UNN. Lean projects are commonly used to transform healthcare organizations for improvements in patient care through the development of a quality driven culture [11]. At UNN, Lean is defined to concern the right things at the right place, time and amount, with a minimum of waste while, at the same time, being flexible and prepared for changes. The Lean process at UNN is organized as a project team, including a project manager, a Lean consultant, a Lean mentor, an economics and an IT-consultant. In addition, the Lean project has an executive board, a project group and a focus group. At the start of the Lean Project, the focus group, which is the actual working group, consisted of; one anesthetist nurse, one theatre nurse, two anesthesiologist, three surgeons, one member of the staff responsible for sterilization of surgical equipment, three staff members responsible for elective surgery planning and waiting lists in the surgery ward, one pediatric nurse, two ICT consultants (one responsible for the EHR), one employee representative, and one user (patient).

Two researchers from our research team have followed the Lean process since the initial group meeting in April 2012. One has participated solely as a researcher, conducting observations during Lean meetings, while the other had an active role and contributed as an anesthesiologist in the Lean process. The researchers observed and participated in more than twenty meetings. In addition to following the Lean process, we have accomplish three weeks of fieldwork at the Operation and Intensive care clinic, conducting observations and unstructured interviews while following an anesthesiologist and an anesthetist nurse in their daily work. We have also conducted thirteen structured interviews with physicians, nurses and administrative personnel.

Data collected through observations and interviews was analyzed together with observational data from the Lean project. Our analytical qualitative approach focuses on the interaction between technical and social factors that produces particular outcomes [31].The preliminary results are limited to the identification of the information needed for pre-operative assessment from the anesthetists and surgeons' point of view.

IV. RESULTS

The observations and interviews, described in section III, allowed the definition and mapping of the generic pre-operative process model shown in Figure 2. A process model facilitates a systematic description of the events permitting the identification of decision activities, and the health worker responsible for each of them. In addition, it allows us to learn about the information flow, and to identify the underlying process issues that are causing the patient assessment information not to be available when required. At UNN, as seen in Figure 2, final pre-operative planning is often done after the patient has arrived for the scheduled surgery. Which means, the final pre-operative planning might me done the day before, or even on the day of surgery. During this final planning process, new information is gathered from patients which may lead to cancellations.

Considering the data collected during the observations and interviews, and the analysis of the existing pre-operative process, all the decision activities were identified and characterized. Based on the information requirements on each of those activities, a new pre-operative process was proposed. In the new pre-operative process the assessment information is requested to the patient at an earlier stage and while the patient is still at home. The assessment information identified as required might be included in the personal health assessment questionnaire which some departments ask the patients to fill out and bring to the hospital when hospitalized for surgery.

V. DISCUSSION

This paper addresses the elective surgery cancellations problem at UNN, a North Norwegian University Hospital. Observations and interviews were conducted at UNN, and lack of information during the pre-operative planning was identified as the main cause of elective surgery cancellations. The problems with the existing pre-operative process were identified and a new process was proposed. In the new process, the assessment information is systematized in a personal health assessment questionnaire, and provided by the patient at an earlier stage, while the patient is still at home.

The mapping of a generic pre-operative process model facilitated the identification of the decision activities, and the health worker responsible. The identification of activities, and their responsible health worker, allowed us to carry out semi-structured interviews to determine the information required to complete the pre-operative assessment. Surgeons and anesthesiologists at UNN considered that the identified information may be provided by the patient. Some departments ask the patients to fill out a personal health assessment questionnaire and bring it to the hospital when hospitalized for surgery. The information classified as required might be included in this questionnaire. Such questionnaires can be sent to the patient through the postal system, and the patient can fill it out at home.

In developed countries, like Norway, where the population is well prepared and able to use ICT (e-readiness), a new approach is possible [32] to promote patient-centered health care [33, 34]. Many patients [35], including elderly or less-educated [36], are strongly motivated to use electronic services [37]. This has been implemented at the Mayo clinic (Rochester, MN, USA) for primary care, with a 40 % decrease of office visits [38]. Increased collaboration with patients, as active participants, through ICT solutions, are also defined as a priority area, as stated in the Norwegian Ministry of Health and Care Services' Coordination Reform [39]. Currently, an extensive ICT investment is taking place in the northern health region of Norway, including at the UNN hospital, our site of research. Helse-Nord, the Northern Norway Regional Health Authority, is investing € 62.5 million in the FIKS (from the Norwegian *Felles innføring kliniske systemer*) project to develop the electronic health record for the future –– a fundamental tool for high-quality patient treatment [40]. The planning tool on the surgical module in the EHR system has been recognized as an unused resource by FIKS, Helse-Nord and the Lean Project [40]. The described health care trends in Norway open new possibilities to approach the elective surgery cancellation problem.

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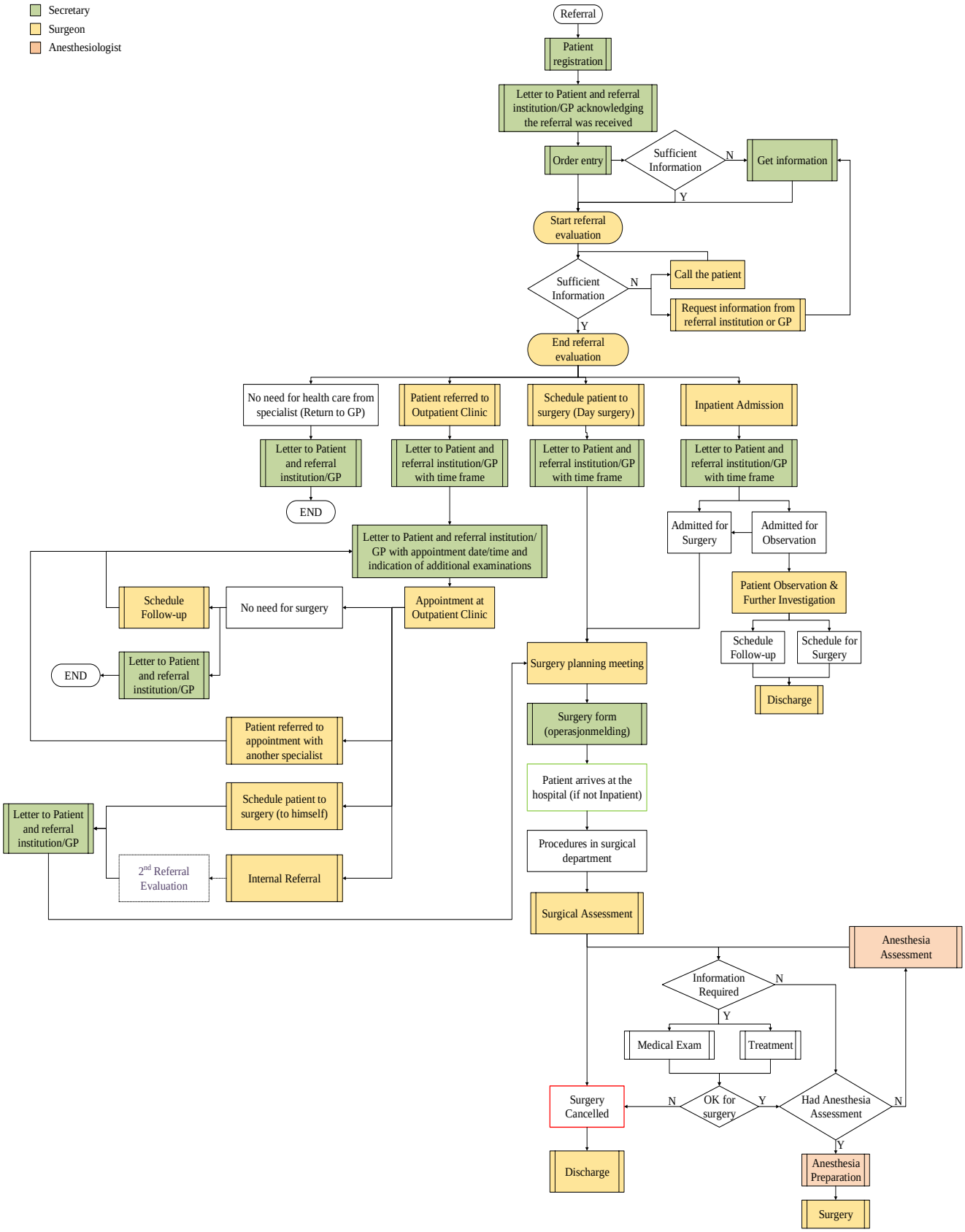

Figure 2. Scheme of the surgery process at UNN. Assessment activities after patient arrival (Box with green border), may contribute to late cancellations (box with red border) while there are many possibilities for hospital-patient interaction at earlier stages (Letters to patient and patient at the hospital).

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VI. CONCLUSIONS

By studying the pre-operative planning at UNN, we have determined that parts of the information flow can be moved to the patient at home. From the work presented herein, we conclude that the assessment information required during the pre-operative planning can be compiled in a personal health assessment questionnaire, and requested from the patient, at an earlier stage.

The authors acknowledge that the paper-based pre-operative planning process proposed is not in line with the best practices suggested in literature. When using the postal system the information flow between the patient and the hospital is time consuming, and it is not possible for the hospital to confirm the reception and submission of the personal health assessment questionnaire. At the same time, due to: (a) the patient prioritization rules in Norway [41], (b) waiting list, (c) and emergency surgeries, surgeries can be delayed and the patient might be requested to complete the personal health assessment questionnaire more than once. On the other hand, when asking the patient to answer a personal health assessment questionnaire from home, the patient might require support from health workers when interpreting the questions, and selecting the relevant information.

The international healthcare trends on paperless and patient focused clinical processes, combined with the e-readiness in Norwegian society, point to new possibilities on how to gather assessment information from the patient at home. To access this information, low-cost communication with patients and their families has been recommended [12]. Thereby improving pre-operative planning, and reducing the number of cancelations, due to lack of information. In order to enable the communication between the patient and the hospital, the interaction with patients should take place through a variety of synchronous and asynchronous secure communication channels, including phone, messaging systems, email, and web-pages.

As patients use several types of communication devices, they should have the opportunity to be contacted on different platforms as well, such as smartphones, pads, and laptops.

ACKNOWLEDGMENT

The authors would like to thank the regional health authority Helse-Nord for funding the research project HST 1119-13 and HST 1125-13. We would also like to thank the personnel at UNN and the Lean project, especially Tonje Drecker.

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The Uptake and Impact of a Personal Health Record for Patients with Type 2 Diabetes Mellitus in Primary Care

A Research Protocol for a Backward and Forward Evaluation

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***Abstract*—A Personal Health Record (PHR) is a promising technology for improving the quality of chronic disease management. Despite the efforts that have been made in a research project to develop a PHR for patients with type 2 diabetes mellitus in primary care (e-Vita), differences have been reported between the number of registered users in the participating primary practices. To gain insight into the factors that influence the implementation of the PHR into daily health care processes and into the possibilities to improve the content, interviews have been conducted with participating primary practice nurses and other stakeholders in the research project. A first impression of the interviews indicated that in many cases, the low impact of the PHR is due to a lack of information about the purpose, content and use of the system.**

Keywords-component: personal health record; type 2 diabetes mellitus; implementation; interviews, contextual inquiry; value specification; summative evaluation

I. INTRODUCTION

A. Personal Health Records

The aging population and increased prevalence of chronic care requires an integral approach to disease management that is well coordinated and consistent with (inter)national care standards in order to support a shift from institutionalized care to home care [1-3]. Disease management may be viewed as a set of interrelated services that spans from prevention and self-management to intramural care for patients with chronic diseases [4-6]. Information- and communication technology (eHealth) will play an important role in disease management, e.g. in providing online support for self-management, in improving information exchange among professionals and with patients, as well as in monitoring the performance of the disease management program [7, 8].

The electronic personal health record (PHR) is a promising technology for improving the quality of chronic disease management [9, 10]. A PHR can be defined as "an electronic application through which individuals can access, manage, and share their health information and that of others for whom they are authorized, in a private, secure and confidential environment" [11], a definition that is adopted by many researchers over the years (e.g., [12-14]).

However, PHRs are becoming more complex and potential functions of current PHRs may not only include sharing clinical and personal data (e.g. history, test results, treatment, appointments), but may also include self-management support, patient-provider communication, information about the illness, peer support or monitoring health behavior data [13].

Potential benefits of a PHR include empowering patients in managing their diseases and the reduction of geographical and communication barriers. This may, in turn, lead to a transition from episodic to continuous care, which has the potential to shorten the time to address disease-related complaints that may arise [12, 13].

Despite these benefits, the use of such systems in diabetes care has only led to small improvements in diabetes quality measures that were of marginal clinical relevance [9], and up to now, evaluations have only provided little insight into why a particular outcome did occur [15, 16]. Consequently, the added value of the existing evidence is often limited for decision making in relation to the strategic direction of implementation efforts [17]. To gain insight into factors that contribute to a successful implementation of eHealth technologies in daily health care processes, it is necessary to look for methodological approaches that go beyond a before and after measurement of health outcomes.

B. The CeHRes Roadmap

The CeHRes Roadmap [18] is a framework that can be used to evaluate and improve existing eHealth technologies. The roadmap states that eHealth development is a participatory process and that development is intertwined with implementation into daily health care processes. Also, it requires continuous evaluation cycles. Through a contextual inquiry and a value specification, a support basis can be created for the development and implementation of the eHealth technology.

C. e-Vita

The PHR e-Vita is an initiative of the Dutch foundation Care Within Reach, a partnership between Philips and

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Achmea, a Dutch health insurance company. Currently, the main content of e-Vita consists of insight into personal health data (e.g., lab values, blood pressure), self-monitoring health values (e.g., weight), education and a coach for reaching personal health-related goals. e-Vita is deployed in primary care in the Netherlands via a trial to study the effects of using a PHR in primary care for patients with type 2 diabetes mellitus (T2DM) (ClinicalTrials.gov number NCT01570140).

Despite the efforts that have been made to develop a technology that has added value in the treatment of patients with T2DM in primary care, we signaled differences in the uptake and impact of e-Vita between the participating primary practices in the research project. To gain insight into the factors that influence the use of e-Vita in primary care, an evaluation via interviews has been conducted. These interviews serve as both a forward (contextual inquiry and value specification) and a backward evaluation to gain insight into the uptake and impact of e-Vita, as well as into the possibilities to improve the content of e-Vita according to health care providers. The outcome of the interviews will provide critical factors for the improvement of the content and the implementation process of e-Vita in primary care. The main research question is:

What factors influence the uptake and impact of a PHR for patients with type 2 diabetes (T2DM) in primary health care, according to primary health care workers and other stakeholders?

In the next paragraphs, we will describe the methods and the preliminary results of the interview study. In the discussion, we elaborate on future research.

II. METHODS

A. Participants

The interview study consists of two parts. In the first part, primary care nurses (PNs) of general practices in Drenthe, in the north of the Netherlands, were invited to participate in an interview. In the Netherlands, PNs are responsible for educating patients about their disease, guiding patients with the use of medication and lifestyle changes and performing health checks. In the e-Vita project, all selected PNs are responsible for explaining the purpose of e-Vita to the participants in the study and administering questionnaires regarding the effects of the PHR. No guidelines for intended use in daily care processes were defined.

To reveal the differences between the implementation processes of practices with high and low numbers of participants, potential practices were selected for the interview study by the means of an inclusion percentage (high, middle, low). The inclusion percentage was calculated as follows:

Inclusion percentage =
*(number of included patients for e-Vita in the study / total number of patients with T2DM in the practice)*100.*

The aim is to conduct five interviews in every group, 15 interviews in total. When primary practices have indicated before that the inclusion of participants was postponed due to explainable circumstances (e.g. long-term diseases among the staff), practices were not contacted to participate in the interview study.

In the second part of the study, five other stakeholders in the e-Vita diabetes project (e.g. project leaders) will be invited to answer questions about their view on the topics as revealed in the first part of this study and the choices that have been made regarding these topics during the project.

B. Design and Procedure

First, semi-structured in-depth interviews were conducted among PNs that already take part in the e-Vita project. During the interviews, questions were asked regarding the purposes, reasons and incentives to use and implement a PHR in their primary practice, the use and the users of the PHR so far, the bottlenecks and barriers that are encountered or expected, the results so far and the way that a PHR will change the primary health care for patients with T2DM and their caregivers in the future. All PNs received a gift voucher of 50 euros for participating.

Based on the identified themes, a second interview scheme will be prepared for other stakeholders in the e-Vita project (e.g., project leaders). These interviews will be used to test the topics as discussed during the interviews among the PNs. These questions are asked via e-mail and validated by telephone. Ethical approval for this study was obtained by the ethics committee of the University of Twente.

C. Analyses

All interviews (among PNs as well as the other stakeholders) will be transcribed and themes and categories will subsequently be coded via open coding, axial coding and selective coding [19]. In this way, recurring themes and items of interest regarding the implementation and use of eHealth technologies in primary health care practice can be identified.

III. PRELIMINARY RESULTS

A first impression of the eleven interviews among PNs so far indicated that, despite respondents' enthusiasm, the PHR has a rather low reach. In many cases, this is due to a lack of information about the purpose, content and use of the PHR. The participating PNs were mostly trained to administer the questionnaires in the research project and little attention has been gone to the content of e-Vita and the integration of the PHR in daily health care routines. Also,

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PNs reported that they find it difficult to promote a platform they hardly know.

Second, little thought has gone towards the integration of PHRs with other health care systems and the integration of the PHRs with national guidelines for the treatment of chronic diseases in primary care.

IV. DISCUSSION

In the current research project, we signaled differences between the inclusion percentages of the participating primary care practices. The goal of this study is therefore to identify the factors that influence the uptake and impact of a PHR for patients with T2DM in primary health care. Because the PNs are responsible for promoting the PHR e-Vita among their patients, we identified the bottlenecks for the implementation of a PHR in primary care from the view of PNs.

We believe that the development of eHealth technologies is an ongoing process that requires continuous evaluations. We therefore conducted both a forward and a backward evaluation in order to not only gain insight into the factors that influence the uptake and impact of a PHR, but also to identify possibilities for improving the content of the PHR in the future.

To understand the choices that have been made regarding the process of development and implementation of the PHR so far, recurring themes in the interviews with PNs will be tested among the other stakeholders in the e-Vita project. To gain insight into the developmental course of the e-Vita, this evaluation cycle is planned to be repeated in the next two years.

Because we feel that the development and implementation of eHealth technologies is a matter of co-creation, we plan to involve both health care providers and patients as potential end-users. Therefore, we will also plan interviews with patients to gain insight into the factors that influence the use of the platform.

At this moment (November 2013), the interviews among the PNs, eleven in total, are conducted. The results of the first part of the study are expected in January 2014. The results of the second part of the study are expected in March 2014.

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Antibiotic Information App for Nurses

Development and Preliminary Effects

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***Abstract*—Antibiotic stewardship programs aim to optimize antibiotic use in order to control antibiotic resistance. Nurses need easily accessible information on antibiotics to perform antimicrobial-related tasks optimally. A task supporting antibiotic information application was developed to support nurses. With log file analysis, scenario-based tests and information behavior questionnaires we evaluated the app. The results show steady, continuing use. Instruction pages are most popular, and first responses to the application are positive regarding look and feel and accessibility of information.**

Keywords-eHealth; antibiotic stewardship; nurse; task-support

I. INTRODUCTION

Mis- or over-use of antibiotics contributes to the problem of antibiotic resistance. Due to their resistance to antibiotics, infections caused by resistant pathogens are difficult to treat. To stop resistance forming and preserve their effectiveness, prudent use of antibiotics is needed [1]. Antibiotic Stewardship Programs (ASPs) aim to optimize antibiotic use in clinical settings. Formulary restrictions, antibiotic cycling, multidisciplinary bed-side consultation and improved diagnostics are some strategies that are used. Infectious disease specialists, clinical microbiologists, pharmacists and physicians work together in ASP to improve antibiotic use. Optimal antibiotic therapy relies on timely adjustment of therapy, based on lab results (diagnostics) as well as careful monitoring of patient progress and vital signs. Correct execution of antibiotic therapy (including preparation and administration of the medications) as prescribed by the physician stands at the base of successful ASPs. In addition to expert input in ASPs, nurses contribute a great deal. Nurses spend much time caring for and observing patients, they are the eyes and ears of the physician and notice changes in patient status that call for antibiotic therapy adjustment.

In earlier research, we already identified nurses as an important stakeholder for ASPs [2], even though scientific literature on ASPs focuses mainly on physicians and clinical experts [3]. As earlier research indicated that nurses have high information needs regarding the antibiotic care process, we aimed to optimally support nurses in their antibiotic-related tasks. We applied human centered design to develop an information application, that takes into account user needs and provides bed-side task support.

Information and communication technology holds the promise of facilitating information transfer and offering support in a variety of health care settings [4, 5]. Applications aimed to support health care workers (HCWs) are abundant, both in mobile applications (for smartphone or tablet) or websites and web apps [6]. However, sometimes apps and websites that are supposed to facilitate and support HCW's jobs are perceived as distracting, user-unfriendly and ill-fitted to work practice, thereby possibly compromising patient safety [7-9]. In some cases, taking a more user- or practice- based focus throughout the design phases may help to overcome these difficulties [8, 10]. Also, incorporating persuasive system design into technology may help to improve uptake and effectiveness. In this model, the targeted behavior is reinforced, shaped or changed by the technology, thereby 'persuading' its users [11]. Designing technology in such way that it is unobtrusive, useful and easy to use helps to blend the technology seamless into users' work (or life) and quickly reach their goals [11]. With regard to nurse support in antimicrobial stewardship, no dedicated applications were identified in literature, as nurses are often overlooked as stakeholder in ASPs. Nurse tasks in ASPs are demanding and ask for good information integration and decision making: nurses gather information from different information systems, integrate it, and decide whether further action is required. We suspect that especially task support and system credibility strategies from the Persuasive Systems Design model are influential; formative evaluations revealed a lack of task support and easy accessible information, which is a barrier for nurse empowerment in ASP [2]. Based on this understanding of the work context, we developed an application.

In this paper, we describe preliminary summative evaluation results of an antibiotic information app for nurses, by focusing on actual use and effects of use on antibiotic stewardship-related tasks. The following research questions guided this research:

1. How is the application being used?
2. Does the application support nurses in their antibiotic-related tasks?
3. Is app-use more efficient than standard information sources ?
4. How do nurses experience the use of the app?

II. THE ANTIBIOTIC INFORMATION APP

Based on formative evaluations, the antibiotic information app was developed [12]. In focus groups, interviews, scenario tests and usability tests nurses in our

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pilot research expressed a need for an easily accessible, centralized information application, where they could find all information on the use of antibiotics they need during their work. This included instructions on preparation and administration, as well as background information and information that is needed on specific occasions only (e.g., when side effects occur). First, a prototype was created in WordPress [13], with some alterations to fit our specific content management demands. Based on its evaluations a final release was launched. The application is web-based, and can be run from the hospital's own server. However, for the pilot the system was made available via the internet, and was taken up in the nurses' personal hospital start page so that it could be accessed easily. Besides PC, the application is optimized for mobile (tablet, smartphone) use. For the app's content, the information sources that were already used by the nurses served as input. These sources were 'chopped up', selecting only the content that is necessary for nurses to execute their tasks (the original sources often contain much information aimed at physicians or medical expert, irrelevant and confusing to nurses). The different types of content are ordered according to the mental models of the nurses as they resulted from the card-sort study. Information is grouped by the following categories: information needed to perform the primary tasks, important information and warnings, general or background information, extra checks and safety information, and information for specialists and medical background (see Figure 1). A demo version (in Dutch) of the app can be accessed via [14].

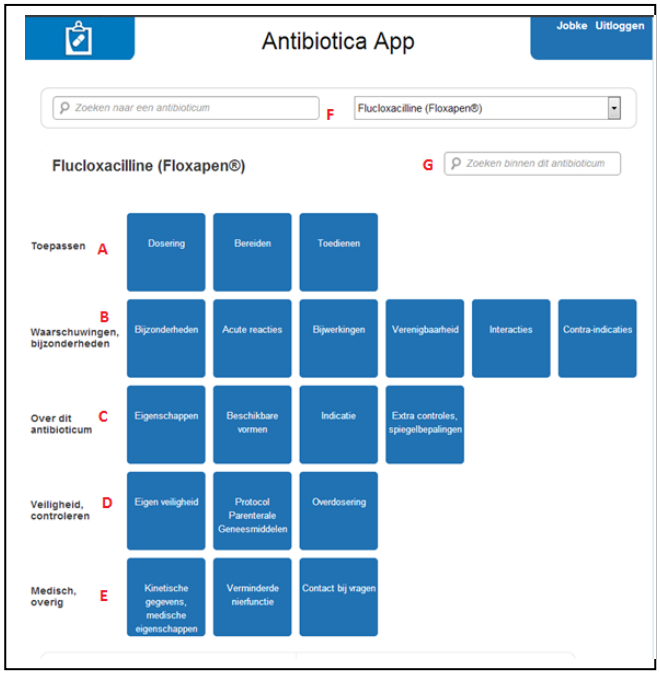

Figure 1. Screenshot of antibiotic overview page. A: task instructions, B:important information and warnings, C: general or background information, D: Safety checks and quality control, E: information for specialists and medical background, F: search field for antibiotic or select from list, G: search all pages (per antibiotic).

By providing easily accessible information, nurses may be better equipped to perform antibiotic related tasks, and are able to recognize and address instances of suboptimal antibiotic use. This supports improved knowledge and recognition of instances to optimize antimicrobial use and nurse empowerment to discuss patient therapy and alert physicians in case of suboptimal antibiotic use. Figure 2 shows an instruction page of the application, where nurses can read how to administer a certain antibiotic, including what to pay extra attention to.

Figure 2. Screenshot of antibiotic overview page. A:back-button B: print and email buttons, C: search field, D: breadcrumb trail, E: instruction block on administration, F: source of the information with link, G: information on last update of the information block

III. METHODS

A. *Participants*

Two lung wards of a local 1000-bed teaching hospital participated in this research. The wards have total of 57 beds. During the pilot phase, 62 nurses (45 FTE) worked at the two wards. A number of them were informed about the app and the importance of antimicrobial stewardship in presentations, all received an email with instructions and instructional fact-sheets on antimicrobial stewardship and the app were distributed repeatedly throughout the wards.

B. *Information behaviour questionnaire*

We created a questionnaire to measure satisfaction and usability of information sources. In addition, items to measure to what extent nurses feel secure and confident to report and discuss suboptimal antibiotic use were added to the questionnaire. The questionnaire consists of existing scales that we adapted to better fit our research questions: To measure to what extent nurses feel supported by the information supply and its usability we adapted parts of Persuasive Systems Design (PSD) questionnaire (task support, persuasiveness, unobtrusiveness) [15, 16], and the

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Website Evaluation Questionnaire (WEQ): relevance, user friendliness, hyperlinks, speed [17]. To measure to what extent nurses feel confident to discuss antibiotic therapy suggestions with physicians we used parts of The Organization and Management of Intensive Care Units, by Shortell and Rousseau (openness, accuracy, understanding) [18], and the Safety Attitudes Questionnaire (teamwork climate) [19]. Lastly, four ASP-specific items and seven items to measure demographics and internet experience [20] were added. Questionnaire items that were originally in English were translated into Dutch and back-translated into English to check for translation errors. The questionnaire was sent by email, and in case of non-response, up to two reminders were sent.

C. Scenario-based user tests

Ten scenarios were created together with a pharmacist and clinical microbiologist. The scenarios present situations that can arise during the nurse's work, eliciting some information need regarding the (correct) use of antimicrobials. The most critical moments in antimicrobial use, where mistakes are most likely and better information could have prevented them, were translated into cases. The cases addressed e.g. interaction of multiple types of medication, administering two or more medications at the same time, (sub) optimal dose due to abnormal weight, etc.

Sixteen nurses participated in the baseline measurement tests, forty nurses will participate in the post-measurements (consisting of two conditions). The participants vary in age, work experience and gender.

During baseline measurement all nurses had no experience with the antibiotic information app and had to resolve the scenarios relying on their usual information sources. During post measurement (in progress), all nurses will have had >6 months of experience using the app (having had >6 months access to it). One group will be randomized into the condition that they have to resolve the scenarios without the antibiotic information application (thus again using their usual information sources), the other group is allowed to use the application. All participants are presented with a scenario, and asked to give a solution (what would you do/needs to be done). They are asked to perform their information-search activities while talking out loud; e.g., look it up in a computer, ask a colleague, call the pharmacist, etc. This activity is recorded on audiotape as well as video.

The audio and video files are analyzed to determine a) whether the scenario was resolved correctly b) what information source(s) was used c) whether any problems arose during the search; and d) how much time was needed to resolve the scenario.

D. Log-file analysis

The application was introduced at the two pilot wards where users could access the application directly on a pc without login. Mobile use was possible only via login. Throughout the pilot we monitored the use of the app to ensure whether it fulfills information needs, at what moment these needs arise most, and what type of content is viewed. The use of the application is being logged using Google Analytics, as well as a Wordpress (the app's software) plug-in [13]. Log information of interest includes visits per day, time of day with most visits, most frequently viewed content and visit duration.

IV. RESULTS

In this paper, we present preliminary results because post measurements and analysis are ongoing. The available results include log file results and baseline measurements.

A. Information behaviour questionnaire

The baseline questionnaire was completed by 27 nurses (24 women, 3 men) out of 64 nurses that were invited to participate (42%). Their mean age was 36 years old (sd 10.4), and on average they had 8.1 (sd 6.1) years of experience working on their ward, and 12.3 (sd 9.8) years of experience working as a nurse. Their internet experience, as measured by the amount of hours they use the internet per day (work and private use) is 2.7 (sd 2.7) hours.

TABLE I. QUESTIONNAIRE OUTCOMES

Information behavior questionnaire	***Subdomain or scale (number of items)***	***Mean score***
Experience, satisfaction and usability of information	Task support (2)	3.0
	Reliability (1)	2.8
	Persuasiveness (3)	2.9
	Unobtrusiveness (4)	1.9
	Relevance (3)	2.7
	User friendliness (3)	2.0
	Speed (2)	1.5
	Hyperlinks (2)	2.4
Nurse-physician communication	Openness (4)	2.7
	Accuracy (5)	2.4
	Understanding (8)	2.2
Safety culture	Teamwork (14)	2.8
Stewardship Climate	ASP-questions (4)	2.3

a. Mean scores are presented per scale. All individual items were scored on a 5-point Likert scale, with scores ranging from 0 (totally disagree), 1 (disagree), 2 (don't agree, don't disagree), 3 (agree), to 4 (totally agree)

With the questionnaire, we measured the following subdomains: Task support: 2 items, Reliability: 1 item, Persuasiveness: 3 items, Unobtrusiveness: 4 items, Relevance: 3 items, User friendliness: 3 items, Speed: 2 items, Hyperlinks: 2 items, Openness: 4 items, Accuracy: 5 items, Understanding: 8 items, Teamwork: 14 items, ASP: 4 items. Table 1 shows the accumulated, averaged scores of all participants on the scale. Negative items were conversed.

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Higher numbers means a more positive score on that domain (e.g., better communication, more persuasiveness of available information sources, etc.). Table 1 shows that although nurses experience the information they use to be supportive of their task, score of 3.0 (on a 0-4 scale), it is not easy or user friendly to find information, given the low scores on unobtrusiveness (1.9), speed (1.5) and user friendliness (2.0). Further, moderately lower scores are found on accuracy (2.4), understanding (2.2) and stewardship (2.3).

B. *Scenario tests*

The reported results are preliminary (see Future Work for planned analyses)

Sixteen nurses were presented with three scenario's each. Nurses needed different amounts of time to resolve the scenario's, ranging from instantly resolving it (ready knowledge), to up to 8 minutes needed to find the information. To complete the scenario's, nurses used the following strategies: read drug instruction leaflet, search pharmacy information website, search on national pharmacologic information site, search protocol database, search in (outdated) print instruction manual, call physician, call pharmacist, ask a colleague, search in Google, and in some cases, the nurse had sufficient (ready) knowledge to solve the scenario.

Among the experienced problems when resolving the scenarios are: difficulty to decide on the correct source to search in, difficulty to access a source (including technical problems/long page loading time/login problems), difficulty to localize and comprehend the precise information needed (re-reading large amounts of text), and more in general, time needed to find the information.

C. *Log file analysis*

Intended use is somewhat difficult to establish. First of all, nurses indicated during development phases that they especially look for instructions when dealing with antibiotics that are unfamiliar to them and this does not happen frequently (otherwise, they would quickly become familiar with the antibiotic and the related information). Further, information is needed when a patient reacts to the medication in an unexpected way (side effect or allergy). Lastly, inexperienced nurses may need to look up information more often than experienced nurses. Thus, information need instances do not arise regularly and are difficult to predict, but when they arise finding correct information fast is important. The application was launched at the end of March 2013, and has been used four times per day on average since. The bounce percentage is 8% (users leaving directly after entering). The log files show a steady use of the application (see Figure 3). Pages that are viewed most, aside from the welcome page and antibiotic overview pages (see an example page in Figure 1), include instructions on preparation and instructions on administration. Information on the antibiotics Amoxicillin-Clavulanic acid and Ceftazidim was viewed most often. The first is used frequently, but the second is used much less on these wards. The users prefer to search for an antibiotic by typing it in the search field; 74% vs. 26% out of 3,060 search instances.

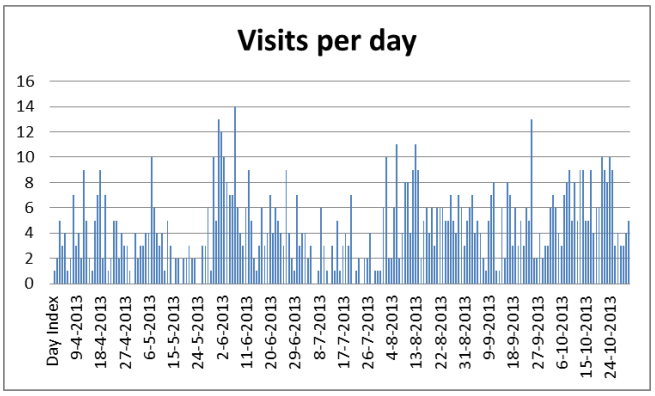

Figure 3. Daily app visits throughout the pilot period.

V. DISCUSSION

A. *Effects on work process*

During development, nurses already proclaimed that having all their information centralized to one location is helpful. However, with the explosion of available medical apps, information systems and other information sources, providing more information is not always better [21]. This is supported by the baseline questionnaire that measured several aspects of information seeking behavior and appraisal. It shows that although nurses show they have good information, it is not user friendly and costs time to find. The scenario-based tests show similar results; nurses loose time locating the desired information. So, information quality is not a problem, finding the right information quickly is. This problem might be overcome with the app, as we hypothesize, because it tailors information and provides chunks that match the information need.

Centralized, tailored information possibly helps to empower nurses in order to function optimally in antibiotic stewardship. Tailored information is one of the areas where the questionnaire and scenario tests results show room for improvement, as well as stewardship culture. For nurses to be able and feel confident to detect and discuss sub-optimal antibiotic use, they need to be able to rely on quickly available information. However, organization safety culture and nurse physician interaction play a big role and need to be addressed as well. Possibly, standardized communication aided with alerts and checklists of when to alarm or discuss with a physician can be useful [22].

B. *App use*

The log file analysis shows that the app does support nurses during their work: use remains steady over time, and the bounce percentage is low. As original sources of information are still available to the nurses, the data show that at least some nurses prefer to use the app instead of conventional materials, as they keep accessing the app,

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months after its release. Relatively little introductory activities were undertaken; some nurses attended an instructional meeting and fact sheets on antibiotic stewardship and the app were distributed. The minimal introduction may have sufficed because the intended users initially proclaimed they liked the concept and look and feel of the app, which has possibly led to increased willingness to start to use the app, and spread the word. It makes a strong case for human centered design, as involvement in the development process generates user commitment. It might be more difficult to reach this type of involvement on a large scale however.

As the most popular pages of the app are instructions on preparation and administration of antimicrobials, task support can be better. Of course, these pages are expected to be visited most frequently, because preparation and administration of antimicrobials are tasks that occur most often, whereas side effects or unexpected progress or deterioration in patient status occurs much less frequent. However, the app should provide support in these not-so-frequent occasions so in the app's evaluation, attention will be paid to precisely what content of the app is most useful to the nurses, and why other content is used less often.

C. Considerations for implementation

Nurses spend much time and effort gathering information, so surely an application that centralizes information has much to offer. However, this implies that somehow the information from different sources needs to be centralized and the ability to do so automatically depends heavily on the information sources that underlie the app. In our case, 'filling' the app and managing its content was done manually because automatizing this process would be too complex and costly in this pilot phase. Individual hospitals and sometimes even individual wards use different information systems, so a one fits all solution may be difficult to achieve. For long term implementation and sustainment this is an issue that must be resolved, for example by assigning quality staff or specialized nurses to maintain information up to date.

With regard to implementation throughout the hospital, nurses outside our pilot ward found the app on the intranet of the hospital and wanted to use it. In this sense, the app implemented itself just by being available. In addition, physicians who the app was demonstrated to were interested in a physician-aimed version. To some extent, the positive reactions to the app can be explained by the fact that often medical information applications are developed and managed by experts. They offer an expert-based view and scope of information. We tailored the various expert-based sources to fit clinical practice, something that is not done often because it costs time, effort, and multidisciplinary cooperation and understanding. Human centered design can help to meet end-user needs [23]. However, when these needs require highly tailored information via applications with dynamic content that need of frequent quality checks and updates, this poses some challenges. Design teams should then find a balance between available resources to manage the information, and generalizability and up-scaling possibilities.

D. Limitations

The outcomes of this research must be interpreted with care because of several possible limitations. First of all, the application was developed and tested with the help of nurses of two wards in one hospital. Generalizing the results greatly depends on the specific information sources in place and the app's effectiveness may differ in other settings. This is to some extent a consequence of the design approach of zooming in in local needs and local contexts. Agile methods can be used for re-design in other wards or institutes. In this case, identification of local information sources and integrating them in the app are among such up-scaling activities.

Further, the questionnaire baseline measurements suffer from a substantial non-response (58%). Even though for survey research this might not be high, given the relatively small sample (64 nurses participated in the pilot) the results must be interpreted cautiously. However, with the scenario-based tests we were able to reproduce some of the questionnaire results regarding nurse experience of finding and using information; the scenario tests show, as well as the questionnaires that this is time-consuming and user-unfriendly.

Another point of caution lies in the operationalization of antibiotic stewardship work processes. To detect the effects of the app on work processes regarding antibiotic stewardship is difficult, especially in a short period. As nurses are not the actual prescribers, the effect of more knowledge and empowerment can only indirectly influence actual use. With the questionnaire we are able to detect some antimicrobial stewardship-related behaviors; e.g., whether nurses give physicians suggestions regarding antibiotic treatment, or alert physicians when treatment seems to be sub-optimal. Besides, we plan to study hospital statistics on antimicrobial use and length of stay to get an indication of possible effects on actual antibiotic use. Antibiotic therapy appropriateness and optimization (adjusting therapy timely based on patient progress) is determined on a per-patient basis [24], as it depends on every patient's unique status (in other words, what 'optimal' is, depends on patient-specific characteristics). Therefore, the effects of the app on antibiotic stewardship would be incomplete when looking at overall antibiotic use alone. So, depending on post-measurement results and the up scaling of the app, per-patient analysis will be done as well.

E. Future Work

In-depth analysis of the scenario-test recordings and transcripts will enable statistical comparisons between the three scenario research conditions: information search *without* app, before implementation; information search *with* app, after implementation; and information search *without* app, after implementation. The conditions will be compared on the following variables: time needed for search, number of encountered problems during search, number of times a scenarios was resolved correctly. Furthermore, scenario

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results regarding encountered problems as vocalized by the participants will be analyzed and grouped. As mentioned before, on a patient basis, changes in quality of care will also be studied using time series analysis on variables such as length of stay, antibiotic use, and mortality.

The application will be introduced on different wards and in other hospitals as well, following short re-design or adaptation of the app and its content to fit local work methods. This broad implementation will be accompanied by evaluations on use and user satisfaction.

ACKNOWLEDGMENT

This project was funded by the Interreg IV "EurSafety Health-net" project. We thank the various participants in the pilot for their cooperation in this research: the nurses, chest physicians of the A4/C4 department, and hospital pharmacists of the Medisch Spectrum Twente hospital in Enschede, The Netherlands.

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Interruption Management for Hospital Communications Systems

A user requirements study

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***Abstract*—Working in a hospital environment requires highly mobile personnel. To facilitate the increasing need for exchange of patient data between healthcare professionals, mobile communication devices are used. Mobile communication devices also increase the occurrence of inappropriate interruptions during clinical task performance. These interruptions have been related to decreased quality of clinical care. User requirements were elicited using a scenario-based approach. The results present insights into user requirements for an interruption management system for hospitals. Hospital workflow protocols were identified as a major source of interruptions. Suggestions by participants for managing these interruptions related to improving workflow using IT instead of merely preventing interruptions. We have shown that even though the hospital is an exceptionally demanding environment, the user requirements for interruption management concur with earlier findings in the broader fields of context aware interruption management and computer supported cooperative work.**

Keywords-Hospital communications systems; interruption management; workflow support; user requirements

I. INTRODUCTION

Medical personnel's working environment requires them to frequently move around during their work and at the same time be able to communicate with colleagues when needed [1–3]. Mobile communications devices, which are used to make this possible, have introduced a new problem; increased interruptions during their work related tasks. Such interruptions increase the likelihood of several negative consequences [4–8].

This situation calls for help to balance between increased availability and increased interruptions. This has been discussed by Solvoll and Scholl [9], who analysed the need and user preference for a better communication system. The CallMeSmart project at the Norwegian Centre for Integrated Care and Telemedicine, University Hospital of North Norway, has presented one approach to solve this problem. In CallMeSmart decision making is supported by a rule-based system. The rules and resulting actions must reflect the wishes of the medical personnel [10].

The purpose of this study is to formally verify and possibly identify additional requirements for a system aiming to achieve our overall goal – to find a way to balance between the increased availability and increased interruptions.

In this paper a user-oriented approach is used to verify and expand identified user requirements for an interruption management system for mobile communications in hospitals. The paper presents the results from interviews and discussions with doctors and nurses concerning interrupts in their daily work situation. This study was previously presented as a poster [11].

II. MATERIALS & METHODS

A. Eliciting User Requirements

Several different techniques can be used to elicit the requirements of a system from the stakeholders. In the early stages of a project, techniques such as interviews (Fig. 1) and user observation can be used to clarify the problem. When some knowledge about the stakeholders and their requirements has been acquired, workshops and brainstorming can be used to define requirements for the system. Carroll [12] argues for the use of scenarios in the design of human-computer interaction (HCI). Lu and Bao [13] propose that context aware service design should be scenario driven process. Benyon and Macaulay [14] lay down a framework for their use in human-computer interaction.

The user-system interaction scenarios can be written based on the previous steps. Creating the scenarios according to a specified framework, as described by Benyon and Macaulay [14], helps to shape it into a multidisciplinary design tool. This is useful since the next step is to formalize the interactions in use cases. A prototype can be used to play out the elicited concrete scenarios and if necessary to refine the service.

The framework laid down by Benyon and Macaulay [14] consist of two main approaches to uncover the design dimensions and their aspects. First the user-centred perspective is characterized by Person, Activity, Context, and Technology (PACT). After the PACT aspects have been uncovered, the designer-centred aspects, Function, Interactions, Content, and Structure (FICS) can be discussed.

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Introduction
Background figures, information, and study aim.
Introducing the interview structure.

Checking user story
Are there any critical situations missing?
Do you think the situations are realistic?

Interruption management
Introducing the CallMeSmart prototype:
- Its context aware features
-The envisioned interruption management techniques

Discussion
Discussing the conceptual scenario and PACT aspects.
-Do you think the concept is useful?

(P) Who do you think will benefit from this system and who will use it?
(A) How and with what purpose would you or others use the system?
(C) When and where?
(T) What kind of devices would benefit?

What will adoption success depend on?

Figure 1: The interview protocol based on the PACT framework.

Hevner et al. [15] describe a framework for information systems research. This framework divides business needs in three categories, People, Organizations, and Technology. The PACT framework seems to mirror these elements. Continuing the framework laid out by Benyon and Macaulay [14] also complies with the guidelines on research conduct, as stated by Hevner et al. [15].

Sutcliffe [16] has also described the use of scenarios throughout the design process. In the first phases of system design he describes his scenarios as 'visioning scenarios', 'scenarios of use', and 'context and use scenarios'. These three types of scenarios again mirror Benyon and Macaulay's [14] framework for scenarios throughout the design process.

Go and Carroll [17] describe the use of scenarios in HCI and requirements engineering. Their article also describes the shift of scenario usage from a single user with a single device to computer supported cooperative work. In a project these different levels of scenarios can also be used, as Benyon and Macaulay [14] also argues for a broad use of different types of scenarios throughout the de-sign process.

Two projects in context-aware systems by Bardram [18]. and Favela et al. [19], similar to CallMeSmart, have also applied scenario design in some form.

Bardram [18] wrote about scenario-based design in computer supported cooperative work. He agrees with Benyon and Macaulay [14] on the dynamic nature of scenarios throughout the process. This work describes various types of records, oriented towards different aspects. The 'organizational' and 'personal' oriented records resemble the PACT aspects. The 'object' oriented record on the other hand, resembles the FICS aspects.

Favela et al. [19] have used a less formalized scenario structure to illustrate typical environment in which their solution has to function and how it does so.

Scenario design and the framework for the actual scenario will be performed according to the framework presented by Benyon and Macaulay [14]. This approach includes the PACT and FICS aspects. The Structure aspect of FICS is however replaced with a Service aspect as presented in other studies [20,21].

Scenarios in HCI design have been used for different and sometimes contrasting goals. Sometimes scenarios are meant to leave room for discussion and interpretation, while on the other hand, scenarios and their adaptations are used to deal with any present ambiguities [14].

In this research the conceptual scenario is supposed to leave room for discussion. The scenario describes a generalized day of a physician, performing several recognizable tasks, such as handover meetings, consultations, surgery, and patient rounds. In this conceptual scenario, the CallMeSmart system is used for managing mobile communications. The scenario was presented and discussed together with a parallel user story, mirroring the same tasks, but without the interruption management system. The complete scenario document is not included here due to space limitations.

Concrete scenarios should eventually deal with any remaining ambiguities, so the system requirements can be clearly defined. After the developers have been involved in formulating the concrete scenarios, the results should be evaluated by potential users before proceeding to the next step. The resulting requirements can then be used to guide software engineers who have not been part of the process so far and have less knowledge about the subject. In this way, a formal user oriented approach is applied, similar to the development of the first prototype described by Botsis et al. [22].

B. Data Analysis

The scenario discussions were recorded and transcribed. The participants' expectations of, and opinions on, interruption management systems were compared to the literature based on the PACT framework, on which the scenarios are based. The focus was on the similarities between the interview results and various parameters and abstractions that are used in context-aware and interruption management literature [23-27].

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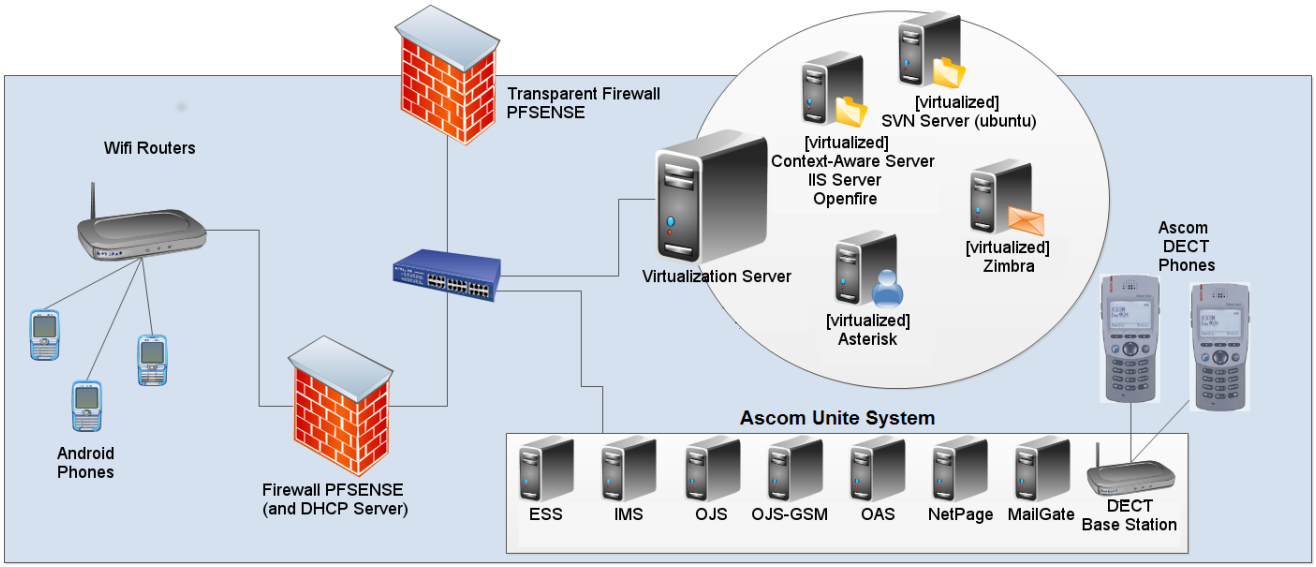

Figure 2: CallMeSmart prototype network structure

C. *The CallMeSmart Prototype*

A working prototype of the CallMeSmart system has been developed. The network on which the CallMeSmart prototype operates is shown in Figure 2. Interruption management can be provided for both android-based smartphones and tablets, as well as for Ascom DECT-phones. The interruption management service itself runs on a server, which also serves as a private branch exchange (PBX). A PBX facilitates in-house phone communications for organizations and businesses, including hospitals.

A context aware application handles data and sends relevant information to a call handling script to provide the correct services at the right moment. For more information on the softphone and android mobile devices, see Solvoll et al. [10]. There are several theoretical frameworks in which CallMeSmart can be placed. Here we will introduce three of them.

De Guzman's classifications of 'receiver oriented', 'negotiated', or 'caller oriented', as presented by De Guzman et al. [23], fit the CallMeSmart system clearly in the 'caller oriented' category. Of these three categories, 'caller oriented' is the only one that doesn't require any attention from the user. In the hospital environment, reducing interruptions would only be achieved by such a 'caller oriented' system.

The CallMeSmart system implements 'burden-shifting', 'time-shifting', and 'activity-based sharing' as used by Lindqvist and Hong [24]. The burden is shifted, because the first step, if a user is busy, is to notify the caller of the user's inferred situation. The options presented to the caller, the interrupter, allow for 'time-shifting'. The 'time-shifting' can be achieved by suggesting using other, conventional, technologies, such as messaging or voicemail.

The design dimension axes of availability sharing, as defined by Hincapie-Ramos et al. [25], can be used to classify CallMeSmart. The system abstracts the sensor data to a 'discrete' 'availability' mode. 'Implicit interaction' is used to present the data whenever necessary. The presentation of availability data is 'asymmetric', since you do not need to share your status to be able to identify the status of the person you're trying to call. When two persons are in each other's contact list, their status sharing could be called 'symmetric'. Connected to the 'symmetry' dimension is the 'traceability'. Here Hincapie-Ramos et al. [25] defined parameters, which do not describe the possibilities for the dimensions they identify as accurately as the parameters in other dimensions. The system can be either 'blind' or 'traceable', according to the framework. This represents the systems options to let users know not only how and when others see them, but also who these others are. In this aspect, CallMeSmart is however two thirds blind. The status callers get to see is the same as the status shown on the user's phone. Information on who has viewed a user's status and when they have done this, is however not being registered. CallMeSmart's obtrusiveness along the axes is 'selectively focal'. On the 'temporal gradient' it focuses on users' 'current availability'. With the identified design dimensions, CallMeSmart adheres quite close to the optimal dimensions identified by the authors. The main difference is the 'blindness' in the information 'asymmetry'.

III. RESULTS

The results presented here are representative quotes from interviews and discussions, which led to interesting new insights. This section is organized following the PACT framework.

Quotes of the three doctors are identified by Dr. A, B, and C. The nurses' quotes are identified with nurse A, nurse B, and nurse C.

Discussing the aspects of the PACT framework led to some interesting insights into the wishes of the intended target environment and users. While discussing aspects of

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the framework, some obtained results were more relevant to other aspects and are presented there.

A. Persons

As nurse A stated:
"The doctors are definitely the ones who are the most disturbed."

Dr. A stated however, that he expected:
"The most advantage is for the caller."

Dr. B made an interesting remark about the sources of interruptions.
"We have incoming calls all the time, from GPs [general practitioners], wanting to ask questions."

Previously Dr. A had already mentioned a possible solution for this, now verified, problem:
"He[a general practitioner] should have an option, if it's urgent he gets through, if not he can wait. It could be very useful for the GP. Including GP's directly, system can help more than switchboard currently does."

Dr. C generalized this even further saying that:
"So many interruptions are from outside the hospital. Personal, from family, or even media trying to call. There should be a barrier to calls from the outside [of the hospital]."

B. Activities

The CallMeSmart prototype has the option to hang up after hearing the callee is busy, without this information being shared with the callee. In a reaction to this feature, Dr. A stated the following:
"I would strongly suggest making it an option to be able to see everyone who has tried to reach you, even if they decided not to leave a message. I guess some people would like to know that."

Nurse A suggested that the possibility for everybody to send text messages will lead to more asynchronous communication.
"[about messages]It's the same as when we started to use e-mail [on desktop computers]. You don't need to synchronize communication."

Dr. C made the same point and voiced the need for a way to handle any backlogs that might occur.
"They will need to prioritize this backlog of communication requests. Maybe color-coded. They should be able to give these prioritizations themselves."

Which was directly in line with Dr.A's request for:
"Some asynchronous feature to allow me to start working, which should also show priorities to the pending messages and call back requests."

To which nurse C added an interesting idea, which however wasn't mentioned by anyone else. The idea is that users should be notified when calls initially directed at the user are successfully handled by a colleague.
"An overview of all calls and messages that don't need further follow-up would be useful."

Two typical answers when talking about the activities aspect came from Dr. B and nurse A respectively:
"If you had a function that could let you say "I'm busy" or "ask me via sms" that would be nice. A function where you set up the busy button as similar to the silent mode, or as a response to a call is feasible to think about."
"Standard messages are a good thing. If I can't reach someone who will be available in a minute I won't have to use my time to find someone else to answer my question.(...) Maybe an option to let the callee know when someone is trying to call and let the caller know when he will be available, though this is an interruption."

An interesting remark from nurse B reflected a topic that came up several times with several participants:
"If you know where a person is, you know he's busy and why and thus call a different person."

C. Context

Two quotes from Dr. A and B respectively, made it clear that they do not want to be disturbed in the operating room (OR).
"The operation setting is the most important one. That's a situation where people really don't want to be disturbed."

"They're always busy in two places, the trauma room and the OR. If you're there, you're busy, that's the name of the game."

Dr. B also stated that the contexts, from which many interruptions originate, are standard situations, dictated by protocols, for example:
"Most nurses are experienced, but need to have the doctors' permission. […] It's like, can I take aspirin or paracetamol for pain, of course, but they have to ask for permission. It's the doctor who's responsible for the patient. That's a very typical situation. It would be nice to have a way to arrange that".

D. Technology

To be able to integrate any solution in the hospital environment, Dr. A advised the following:
"I would be careful to exclude options, someone might prefer the pagers."

Dr. C clearly stated an issue that came up more often.
"It would be nice if you could use the system on a device like an iPad and have information, like the EPJ, integrated."

E. System Adoption

A subject that came up with all the participants was clearly stated by nurse A:
"It is more the culture to want the answer now. You need to teach the people that they don't need the answer right now."

Dr. C formulated an issue that was mentioned by all doctors participating in this research:
"If the doctors can't trust the system to be consequent and reliable, they will go back to their old system."

A concerned voiced by several participants was explained by Dr. C in the following way:
"Doctors will be the main users of the system. They might however try to use the system to put up a cocoon around themselves, using it as a barrier and not as a tool. Some doctors currently switch of their phones, or never turn them on. They might use the system in a similar way, always keeping their phone on busy."

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IV. DISCUSSION

Widya et al. [20] pose that scenarios should be very domain specific for participants to recognize the situations. In the CallMeSmart project, more general scenarios have been used. This was intentionally done for several reasons. The first of which is that the CallMeSmart system is meant for many different sub-domains inside the hospital. It also enabled discussions of the scenarios with healthcare staff from the various disciplines, which were available for this research. Even though it was not very domain specific, several interviewees spontaneously noted that they could relate to it.

There was, however, one physician who felt unable to participate in this research. This was because the physician did not recognize personal work situations in the scenario.

When the system is being customized for a hospital and its departments, very domain specific, detailed, accurate scenarios can be used. The local policies, user habits, and preferences can then be taken into account. The current scenarios are also quite fragmented. This fragmentation is the result of the systems' wide range of functions and options for the varying situations. Since many functions are replacing functionalities of current communication systems, they could be given less attention in future user requirement research.

Only a limited number of medical staff participated in this study. They were from widely varying backgrounds, which had several consequences. The results represent requirements of a wide variety of hospital workers, i.e., nurses, an anaesthesiologist, a surgeon, and a department head. The participants did not, however, discuss the results with their colleagues. It could be that the current results include personal opinions or suffer from oversight.

A. Persons

One might expect doctors, as senior responsible staff, to gain the most benefit from interruption management. During interviews however, both doctors and nurses brought up the benefits they expected the interrupters would gain. Interruptions are generated by a need for information to accomplish a task. Proper interruption management would have to deal with these information requests, thus facilitating the work of the interrupters.

It was interesting to note that medical personnel seemed very annoyed by calls from outside the hospital. It could mean that either the volume of interruptions is indeed high, or that these interruptions more often occur at inappropriate moments, due to even less knowledge about the availability of the callee for the callers. Either way, this source of interruptions should be considered in designing an interruption management system.

B. Activities

One of the doctors made an interesting remark on the symmetry of information sharing. When the CallMeSmart system intervenes, a caller can infer information about the person in question, thus enabling the need for traceability measures, as discussed by Hincapié-Ramos et al. [25].

The expected increase of asynchronous communication has been shown to increase efficiency in hospital work [7]. Managing these communications could further increase the efficiency.

It is interesting to note that users came up with ideas for handling interruptions in ‘receiver oriented’, ‘negotiated’, and ‘caller oriented’ approaches, as described by De Guzman et al. [23]. They also expressed a strong preference for interruption management not only ‘during switch phase’, but also ‘after switch’, as described by McFarlane and Latorella [26]. The notion to classify communications by priority will probably suffer from the same mismatches in perceived urgency between users as described by Wu et al. [7].

‘Awareness’ or ‘presence’ cues were suggested as a way to reduce interruptions. These cues can be visualized by icons and represent contextual information, such as location. The CallMeSmart project does not have this feature, as it requires extra time investment from the users, every time they want to make a call. This was assumed to be unfavorable for efficient system adoption and the good results achieved by Oulasvirta and Petit [27] were not expected to be reproducible in a hospital environment.

C. Context

All participants emphasized the significance of interruptions on the OR. They emphasized that the first problem that should be solved are interruptions on the OR and ER. Even if a system would only solve interruptions on these locations they would like to try it.

D. Technology

Including options to integrate the different devices could lead to higher adoption rates, because it doesn’t require users to switch to a new device. It would however also give users the option to handle a larger variety of interruptions via mobile communication devices. The use of tablet devices to handle interruptions could lead to more mobile workflow support of users, while their information requests to each other can be managed by CallMeSmart.

E. System Adoption

Three main issues for adoption were identified. Firstly, hospital personnel will have to get used to asynchronous communication. Secondly, the system should be reliable, consistent, and transparent for users to understand its functionality. Thirdly, users will have to be loyal to the system, using it in the way it is intended. Trying to use the system as an extra barrier all the time will not lead to successful implementation.

F. Insights gained

The potential users suggested new ways of managing interruptions, but also suggested integration of the communication system with other hospital IT systems.

Though the interviews yielded a lot of ideas on interruption management, many of the mentioned causes for interruptions originated from workflow protocols. The participants would often offer solutions which would change the workflow. This is interesting because of the comments

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on system adoption, where participants stated it should not require change to the current processes.

Although the study included only a limited number of participants and the results might therefore not be generalizable, it is suggestive that their opinions do highly correlate to the literature of the wider field of context-aware interruption management.

The study aims of Bardram and Favela, to support computer workflow instead of managing interruptions directly, is interesting [18,19]. According to our findings, supporting workflow could further reduce the need for interruptions.

V. CONCLUSION AND FUTURE WORK

The requirements, elicited using scenarios, match with the broader literature of interruption management and previously identified requirements. Wishes of medical personnel adhere to previous literature in the broader fields of context awareness and interruption management. Computer supported cooperative work is closely related to interruption management due to its potential to reduce the need for interruptions.

The CallMeSmart system has been further developed according to the feedback from the users and is now ready to be tested in clinical settings. This pilot will start during January 2014, and CallMeSmart will first be installed and tested at the Oncology department at University Hospital of North Norway. The results from this pilot will be published during and after the pilot, late 2014 and 2015.

ACKNOWLEDGEMENT

This work was supported by Norwegian Research Council Grant No. 174934. We would like to thank the doctors, nurses, and developers who participated in the process.

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Nursing Professionals' Roles in Terms of Communication with Patients Using Electronic Devices

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Abstract: **The purpose of this study is to gain understanding of nursing professionals' expectations of their roles in terms of communication with patients using electronic devices. A quantitative design was used in the study. The target group of the study comprised the nursing professionals who worked in outpatient clinics, appointments, or reception services within either special or primary health care in one hospital district in Finland. The data was collected by an electronic questionnaire developed for the study and was analyzed by descriptive statistical methods. The nursing professionals were asked to choose the two most important roles that they thought described their own role in terms of communication with patients using electronic devices. The alternatives given were: learner, advisor, collaborator, teacher and limit setter. The descriptions of the roles were developed in the researcher's (MK) earlier study. Most often the professionals chose the role of collaborator where they communicate with patients by electronic devices. The role of collaborator was chosen 102 times. The second most common choice was advisor, which was chosen 64 times, while the least popular choice was the role of limit setter. Patient-centered care and shared decision-making require that professionals collaborate actively with patients. The findings show that the members of nursing staff estimate their role to be that of collaborator and so they want to be partners in cooperation with patients. We can assume that nursing professionals are ready to utilize electronic devices in communication in concert with patients.**

Keywords-electronic communication; information technology; role relationship

I. INTRODUCTION

Nursing professionals have a critical role in communication with patients in health care. They can provide individuals with timely, effective and appropriate services and assist in safeguarding patients' rights at treatment facilities [1, 2]. Nurses establish a caring relationship where both parties work together helping patients to cope with their health problems [3].

Traditionally, nurses have been seen as servants who follow the physician's instructions and ensure that patients receive high-quality care [4]. In addition, nurses' role has been that of patient advocate, promoting health by giving information and educating patients. A key role is to support the patient as an independent survivor [5].

While nursing staff was earlier seen as information providers, the trend in communication and patient education in the 2000s has shifted towards collaboration between patients and professionals [6, 7]. Nurses often have the role of coordinator in patient care. They are responsible for discussing patients' status with the patients themselves but also with family members and other health care professionals [8]. Thus, nurses need a wide range of communication skills and have a variety of communication situation related roles.

Reciprocity and simultaneousness are central aspects in communication [3]. It attempts to build a confidential and equal partnership between professionals and patients through communication [9].

Using the Internet for seeking health information and electronic devices for communication has become a popular choice in healthcare [10]. Today, the Internet is an easily available tool [11] and citizens are able to be in contact with healthcare staff via remote connections [12]. Patients are interested in using electronic applications for appointments [13], for looking at their own patient records [14] and for satisfying their health information needs [15]. The use of different reminder messages that are transmitted via mobile phone is also becoming more popular [13].

The use of modern technology, such as mobile phones and email, can enhance communication between patients and health care professionals. It is possible that the use of information technology makes nurses' work more independent. For this reason, nurses' awareness of their

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roles and skills in electronic communication will be critical for efficient service delivery [16].

According to earlier studies, the use of information technology applications for communication requires new skills, roles and attitudes on the part of staff in health services [17]. It is clear that face-to-face communication is different from virtual communication [18]. It can be expected that cooperation with patients becomes more significant than before when electronic applications are used because the professional must be able to clarify the patient's situation and needs, sometimes without eye contact [19]. It is not possible for the professional to perceive and interpret the patient's physical reactions, expressions and gestures which might provide valuable additional information about the patient's situation and health status [20]. However, it is possible to use videophones and other computer applications that relay images. When using these tools communication becomes nearly the same as face to face [21].

Information technology is widely used in Finnish health care organizations. Electronic patient records are in comprehensive usage both in specialized health care and primary care. Its distribution covers 100% of these health care providers [22]. However, electronic communication is not as common between patients and health care professionals.

In this study, communication means patient-professional interaction which takes place with the aid of electronic devices. The key is to examine nursing professionals' roles in this communication from professionals' point of view. Electronic devices refer to the devices which belong to the field of information and communication technology: computers, mobile phones, videophones and various applications (e-mail, text messages transmitted with a mobile phone and Internet software, electronic forms, Internet applications), which make electronic communication possible between nursing professionals and patients.

When the use of electronic communication becomes more common in nurses' work, it is important to examine how nurses experience their own roles as service providers by these applications. New working methods may change the work of nursing staff in such a way that the changes must be taken into account in the training or during the job orientation period.

The purpose of this study is to gain understanding of nursing professionals' expectations of their roles in terms of communication with patients using electronic devices.

The research questions were:

1) How do the nursing professionals experience their own role in electronic communication with the patients?
2) Do the professionals' experiences of their own role in electronic communication differ in special health care and primary health care?
3) Do the experiences of different occupational groups regarding their own role in electronic communication differ from each other?

The study is part of a wider project whose objective is to clarify nursing professionals' experiences of the use of electronic communication in Finnish public health services.

II. MATERIAL AND METHODS

A. Design and data collection

A quantitative design was used in this part of the project. The target group of the study (N = 567) comprised the nursing professionals who worked in outpatient clinics, appointments, or reception services within either special or primary health care in one hospital district on the west coast of Finland.

The data was collected in spring 2012 using a structured questionnaire developed for the study. The survey was carried out in electronic form using the Webropol® service. The participants got the link to their personal e-mail and were able to answer the questions using the link. In one organization, the staff did not have e-mail addresses and the questionnaire was delivered to them as a paper version.

The survey instrument was organized into four blocks of questions: a) background characteristics, b) electronic communication with patients, c) electronic communication with colleagues, d) nurses' roles in electronic communication. This paper concentrates on block d; the findings of the other blocks will be reported elsewhere.

In block d, the participants were asked to choose the two most important roles that they thought described their own role in terms of communication with patients using electronic devices. The given alternatives were: learner, advisor, collaborator, teacher and limit setter. The descriptions of the roles were developed in the researcher's (MK) earlier study which was carried out in psychiatric nursing (see Table 1). The study aimed to identify nurses' roles in systematic patient education sessions where also computer-based education was used [23]. In the present study, the target group received a short description of the roles in the questionnaire.

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TABLE 1. DESCRIPTIONS OF THE ROLES

Role	Description of the role
Limit setter	You feel it is your task to set limits e.g. to the information that is given to the client utilizing electronic devices.
Teacher	You feel above all that you provide information for the client by making use of electronic devices.
Collaborator	You feel you work in cooperation with the client in utilizing electronic devices.
Advisor	You feel you are a guide who utilizes electronic devices as you give information to the client.
Learner	You feel you learn new things about the use of technology, the relationship between client and nurse, the client's health problem and treatment etc.

B. *Ethical considerations*

The data collection was authorized by the nursing or medical directors of the study organizations. The basic principles of research ethics, such as confidentiality and good study practices, were followed throughout the study [24]. The target group was informed of the purpose of the study and the participation of the nurses was voluntary.

C. *Data analysis*

The statistical software package SPSS for Windows version 20 was used to analyze the data. Descriptive statistics were computed for background information on organization and occupational groups. Nursing professionals' choices of their roles in electronic communication were looked at from the software using frequencies. Because of small sample size in some job areas (charge nurses, practical nurses, physiotherapists and occupational therapists), the groups had to be pooled for statistical analyses. Chi-squared tests were used to determine the differences in background factors between the professionals' role choices.

III. RESULTS

Out of 567 eligible participants in the sampling frame, 123 answered the questionnaire (total response rate 22%). 23% of the participants worked in specialized health care and 77% in primary care. There were 34% nurses among the respondents, 46% were community nurses, 7% charge nurses, 7% practical nurses and others, and 5% were physiotherapists and occupational therapists.

The participants chose the role of collaborator 102 times when they estimated their own role in communication with patients by electronic devices. The second most common choice was advisor's role, which was chosen 64 times. The most infrequently chosen role was that of limit setter, which was chosen eight times. (Figure 1)

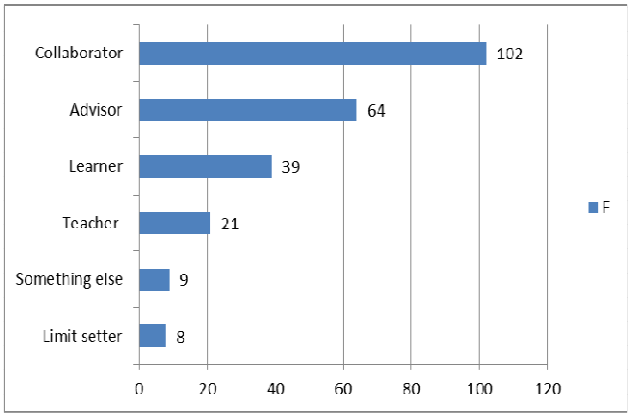

Figure 1 – Nursing professionals' roles in terms of communication with patients using electronic devices (F = the count of the choices)

There were no statistically significant differences in professionals' experiences of their own roles in electronic communication with patients between staff working in special health care and primary health care. (Table 2) Similarly, there were no differences between occupational groups. (Table 3)

IV. DISCUSSION

Our study showed that the use of electronic devices in communication between nursing professionals and patients might not change staff roles in practice compared with face-to-face communication. This was supported by the study findings showing that nurses were seen as collaborators with patients when they used various information sources for giving information to patients [6, 24]. It is clear that the use of electronic devices does not remove the role of advocate for patients from nursing professionals. Compared to traditional practice, possible remote services require different sensitivity on the part of nurses to identify patients' situation and needs.

It is traditionally thought that nursing practice requires close face-to-face interaction. It can therefore be natural for nursing professionals to tend to collaborate actively with patients instead of using electronic devices for communication. On the other hand, it can be supposed that nurses choose more often the role of teacher because patient education has a significant role in client-nurse interaction and it often involves actual teaching.

However, it is clear that professionals should be ready to tailor their roles according to the patient's situation. In the present study, some of the participants were community

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nurses who worked in school health care. Their patients are young children, so it can sometimes be important that the professional takes the role of limit setter. A competent and expert health care professional can operate flexibly. She or he can recognize different situations and patients' needs when electronic devices are used in communication.

There were no differences in nursing professionals' experiences of their own roles in electronic communication with patients between staff working in special health care and primary health care as distinct occupational groups. It is probable that nursing professionals' work does not differ very much in outpatient clinics between special and primary health care organizations. Communication with patients is a significant part of nursing professionals' work and they use varying roles in practice regardless of the structure of the organization. Perhaps the most crucial factor that may affect the choice of the role of nursing professionals is the patient's situation.

The study had some weaknesses. First, nursing personnel's participation in the survey was not very active, which may limit the generalizability of the findings. The study was performed in one hospital district area in Finland. It was known that the use of electronic devices for communication was not very common in this area. For this reason, is possible that nursing staff members were not interested in responding to the questionnaire. It may be that some of the nurses did not have much experience of electronic communication, which is why they found it difficult to look at their own role in it.

Second, the descriptions of the roles were developed in a systematic patient education project in the area of mental health nursing. Now they were tested for the first time in other nursing areas. However, we have no reason to believe that these limitations appreciably biased the findings. The results are suggestive and describe the situation among the target group.

Our results show that nursing professionals have competence to use electronic systems in various ways for communication with patients. Therefore, there are no explicit barriers to the implementation of new applications for daily care. It is not self-evident that new applications will bring immediate economic benefits and working time savings, but there is some evidence that they increase access to health care services, thus helping patients [25]. For this reason, is important to ensure nurses' role and competence in electronic communication.

V. CONCLUSION AND FUTURE WORK

According to the study, nursing professionals assume different roles in communication with patients using electronic devices. Most often nursing staff members think of themselves as collaborators. The findings show that professionals estimate their role to be collaborators, and we can thus suppose that they want to be partners in cooperation with patients. Patient-centered care and shared decision-making requires that professionals collaborate actively with their patients.

It seems that the introduction of electronic communication devices in health care does not cause a problem from the point of view of professionals' working methods. The results can be used in nursing education and orientation to ensure nursing professionals' abilities to communicate with patients using electronic devices.

In future, it is important to investigate electronic communication from the patients' perspective. It is necessary to find out patients' expectations for nurses when services are transferred to electronic format.

ACKNOWLEDGMENT

The study was partly funded by Satakunta Hospital District (EVO 81051) and the Finnish Cultural Foundation, Satakunta Regional fund.

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TABLE 2. NURSING PROFESSIONALS' ROLES IN TERMS OF ELECTRONIC COMMUNICATION IN SPECIAL HEALTH CARE AND PRIMARY HEALTH CARE

Organization		**Collaborator**		**Advisor**		**Learner**		**Teacher**		**Something else**		**Limit setter**	
	n	yes %	no %	yes %	no %	yes %	no %	yes %	no %	yes %	no %	yes %	no %
Special health care	28	86	14	64	36	25	75	11	89	7	93	0	100
Primary health care	94	83	17	49	51	34	66	19	81	6	94	7	93
Chi2 (df) p		0.118 (1) 0.734		2.038 (1) 0.156		0.811 (1) 0.372		1.077 (1) 0.303		0.020 (1) 0.888		2.212 (1) 0.139	

TABLE 3. OCCUPATIONAL GROUPS AND THEIR ROLES IN TERMS OF ELECTRONIC COMMUNICATION

Position		**Collaborator**		**Advisor**		**Learner**		**Teacher**		**Something else**		**Limit setter**	
	n	yes %	no %	yes %	no %	yes %	no %	yes %	no %	yes %	no %	yes %	no %
Nurse	41	83	17	46	54	32	68	17	83	10	90	5	95
Community nurse	56	84	16	57	43	34	66	14	86	2	98	9	91
Other	24	79	21	50	50	6	18	25	75	17	83	4	96
Chi2 (df) p		0.269 (2) 0.754		1.158 (2) 0.643		0.624 (2) 0.654		1.348 (2) 0.519		5.888 (2) 0.546		0.919 (2) 0.950	

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Intravenous Drip Infusion Monitoring System with Body Area Communication Tag

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Abstract— **Intravenous drip infusion is a common method of administering medication. However, it is difficult for a nurse to continuously monitor the administration since it can take more than one hour. It is difficult to instantly detect problems such as removal of a drip infusion administration set by a patient or an empty bag. We propose an intravenous drip infusion monitoring system equipped with body area communication tags that can instantly detect such incidents.**

Keywords- intravenous drip infusion; body area communication tag; medication; medical administration

I. INTRODUCTION

Intravenous drip infusion is widely used for administering medication in hospitals. However, it is difficult to continuously monitor administration, since it can take more than one hour. Therefore, it is difficult to instantly detect incidents. The following incidents should be monitored.

- Infusion rate: Changing of infusion rate causes insufficient therapy or serious problems.
- Empty medication bag: Empty medication bag sometimes results in a blocked cannula by blood and has to be exchanged with a new one.
- Remaining quantity of medication fluid in the bag: It is possible to estimate changing of infusion rate and empty medication from the remaining quantity of medication fluid.
- Getting the drip administration set off the body: Getting the drip administration set off results in insufficient therapy. In case of administering toxic medication such as anticancer drugs, a skin with which toxic medication oozing through a cannula is stained sometimes becomes necrotic.

Several types of intravenous drip infusion monitoring equipment have been developed. Optical devices, such as Ir-da, are widely used to measure the drip rate [1][2][3][4][5]. Ogawa et al. developed a system for measuring the drip rate using electrodes instead of optical devices [6]. However, the drip rate is not steady, and the size of the drip is not the same [7]. Generally, lower the drip rate, smaller the drip size. For steady and accurate infusion, it is necessary to equip an ordinary administration set with some form of servo-control mechanism. Barros and dos Santos proposed not only monitoring the drip rate but also controlling it to maintain steady and accurate infusion [1]. However, since their system estimates the infusion rate from the drip rate and does not take into account the change in drip size, it is difficult to accurately estimate the infusion rate. On the other hand, Wang and Chen estimated the infusion rate instead of the drip rate using an ultrasonic transducer [8]. Cataldo et al. proposed a measuring scheme to estimate the remaining quantity of fluid in a bag. They used the microwave time-domain reflectometry (TDR) to estimate this [9][10]. Their system can measure the infusion rate from the remaining quantity, not the drip rate. Huang and Lin proposed a warning system using Radio Frequency Identification (RFID) to detect an empty bag [11].

Current systems and tools cannot detect getting the drip administration set off the body. Some cognitively impaired patients consciously remove their drip infusion administration sets by themselves. Hence, a monitoring system that can detect such behavior is needed. We propose an intravenous drip infusion monitoring system that can detect both an empty bag and removal of a drip infusion administration set. We previously presented the results of a feasibility study of our proposed system [12]. We use body area communication tags called the Touch tag to estimate both actions. The Touch tag is developed and supplied by Adsol Nissin Corp. [13].

After related work is discussed in Section II, we describe the basic principle and structure of our proposed system in Section III. The basic characteristics of the proposed system are presented in Section IV. The experimental parameters of the system and evaluations we conducted are described in Section V. The key points are summarized and future work is mentioned in Sections VI.

II. RELATED WORK

In this section, we introduce schemes for detecting the remaining fluid in a bag and body area communication tags, which are related to our system.

A. Schemes for detecting remaining fluid in intravenous bag

Cataldo et al. used microwave TDR for a two-strip adhesive probe attached to a bag to estimate the remaining

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quantity of fluid in the bag, as shown in Fig. 1 [9][10]. The TRD value varies corresponding to the remaining quantity of fluid. The measuring accuracy may be acceptable. However, since it requires a TRD measuring instrument, such as a network analyzer, and to measure TRD value vs. remaining quantity of fluid for kinds of bag or medication.

Huang and Lin used RFID to detect an empty bag [11]. A RFID tag is attached to the bottom of an intravenous bag. They argued that a tag reader could read a RFID from a few meters during fluid level was under a RFID tag, as shown in Fig. 2. However, they did not provide practical experimental data on if a tag reader could read RFID.

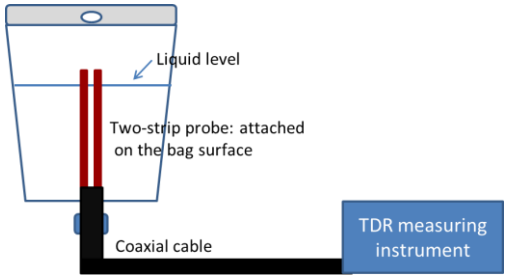

Figure 1. Scheme for measuring remaining liquid quantity using TDR

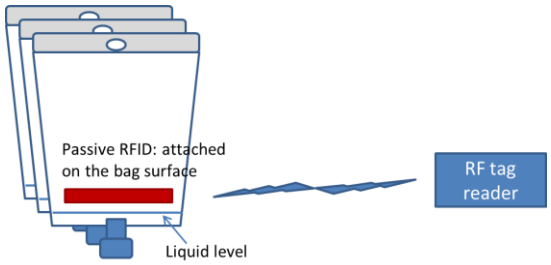

Figure 2. Scheme for detecting an empty bag using RFID

B. *Body area communication tag*

There are two types of body area communication systems [14]. One involves the human body as a data-bus between devices attached to the body. The other involves a radio system used as a communication system between devices attached to the body. The first type was invented by T. G. Zimmerman in 1996 [15]. His body area communication system used the variable of the electric field on the body of which the frequency range was from 0.1 to 1 MHz. He built a prototype operating at 330 kHz. However, since he chose a frequency range from 0.1 to 1.0 MHz to suppress electric-field emissions, probably it was difficult to achieve stable communication because of the significant ambient noise. Ambient noise usually presents itself at frequencies below 1 MHz. When the transmission signal is strong enough to maintain stable communication, there is no difference between his system and existing near-field communication systems such as WiFi and Bluetooth. Ultimately, Zimmerman stopped developing this technology and chose the second scheme.

Panasonic Electric Works Co. Ltd. developed a touch communication system using the variable of the electric current in a body instead of the electric field to avoid the ambient noise in 2004 [16].

Yuichi Kado evolved Zimmerman's body area communication system [17]. He selected the frequency band from 5 to 10 MHz to avoid the ambient noise and developed a modulation scheme to efficiently modulate the electric field near the body and receiver circuits which reduce ambient noise such as electrical hum.

Our partner, Ad-Sol Nissin Corp., introduced a semi-active scheme to improve the battery life cycle of tags used in evolved electric field schemes [13]. It is possible to use a tag for a few years without having to replace the battery. We chose Ad-Sol Nissin's Touch tag to develop a medication error protection system [18], since it is possible to communicate over clothes or shoes and the life cycle of the tag is long. The Touch tag was used for verifying the relationship among an intravenous bag, patient, and nurse. We noticed that the received signal level when the Touch tag was touched directly was different from the level when the tag was touched through an intravenous bag.

III. BASIC PRINCIPLE AND SYSTEM STRUCTURE

A. *Basic principle*

Our system uses Touch tag features to detect an empty intravenous bag and a removal of a drip infusion administration set. The Touch tag reader sends a calling signal over the electric field for the Touch tag to send a reply message. The tag that received the calling signal sends a reply message including its ID over the electric field. Therefore, the tag reader can read the ID in a tag a few centimeters away from it without requiring any media. In addition, when there are ionized media, such as isotonic sodium chloride solution, in a tube between a reader and tag, the distance from where the reader can read the tag becomes longer. When a person touches the tube between a reader and tag, the communication length becomes very short. The reason is that the electric field generates between a tag and the ground via a person in addition to a section between a reader and tag, and the strength of the electric field between a reader and tag weakens.

It is possible to detect an empty bag by changing from able to read a tag to unable to read a tag derived from fluid in a tube being empty.

The removal of a drip infusion administration set is detected by changing from unable to read a tag to able to read a tag, because of the patient removing the tube and the tag together with the cannula. The tube was attached to an arm or other body parts of a patient before removing. It is difficult to detect if a patient removed only the cannula. However, we believe that a cognitively impaired patient may remove the tube and tag together with the cannula.

B. *System structure*

The structure of our proposed system is shown in Fig. 3. A tag reader is attached to a tube beneath a chamber, Tag_1 is attached to the tube at longer than the longest position that a reader can read a tag's ID when there is no fluid in the tube

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(L_1), and Tag_2 is attached to the tube between the shortest position that a reader cannot read a tag's ID when a person touches it (L_2) and the longest position that a reader can read a tag's ID when there is fluid in the tube (L_3). L_1, L_2 and L_3 are lengths from a reader. An arm is attached to the tube at a position near Tag_2. Not reading Tag_1 means the amount of fluid in the tube is nothing; and reading Tag_1 and Tag_2 simultaneously means the tube was removed from an arm. When a PC detects no amount of fluid in a bag or a tube has been removed, it sends an alert to the nurses' station. Only Tag_1 is needed for detecting only an empty bag. On the other hand, only Tag_2 is needed for detecting a removal of a drip infusion administration set.

One of the advantages of the proposed system is that installation is very easy. Attaching an electric-probe or an RFID on a bag is not necessary. Installation only involves fastening an electrode of a reader and one or two tags to a tube. For this research, the electrode of a reader was fastened using magic tape and a tag was fastened using a rubber band, as shown in Fig. 4. Fastening becomes easier to change them to clipping type.

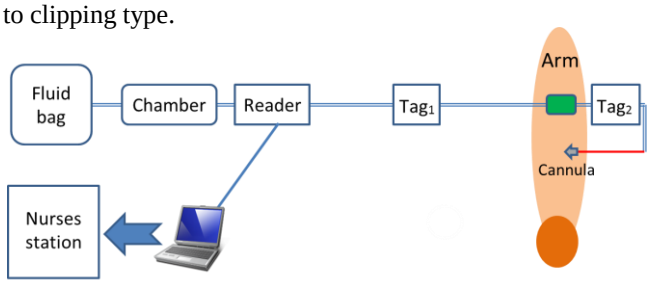

Figure 3. System structure

IV. BASIC CHARACTERISTICS

A. *Humidity*

Since the touch tag is an electric-field-type tag, we assumed L_1, L_2 and L_3 would be affected by humidity. We measured the relationship between L_1, L_2, L_3 and humidity for two tags on three different days, as shown in Fig. 4. This photo shows when measuring L_2. We used a bag filled with an isotonic sodium chloride solution.

An electrode of the reader was attached to a tube beneath a chamber with magic tape. A tube was attached to a patient's arm between an electrode and a tag with gummed tape, and Touch tags were attached to the same tube with a rubber band to easily change their positions. Since a reader can surely read a tag at less than or equal to L_1 or L_3, the measured data were of the longest length on which a reader can read a tag continuously 10 times. The other hand, since a reader surely cannot read a tag at longer than or equal to L2, the measured data were of the shortest length on which a reader cannot read a tag continuously 10 times.

The measurement data of L_1, L_2, and L_3 are shown in Figs. 5, 6 and 7, respectively. We could not find any effects of humidity on the readability of touch tags. The reader could not read a tag 18 cm away, when there was not fluid in a tube, as shown in Fig. 5. Therefore, Tag_1 must be attached to a tube more than 18 cm from the reader-electrode. The reader could not read a tag's ID more 60 cm away, when someone touched the tube, as shown in Fig. 6, but it could read the tag within 84 cm, when there was fluid in a tube, as shown in Fig. 7. From these experimental data, Tag_2 must be attached to a tube between 60 and 84 cm from the reader-electrode.

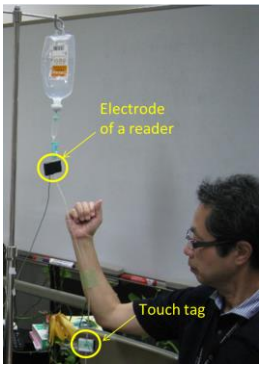

Figure 4. Photograph of measuring L_2

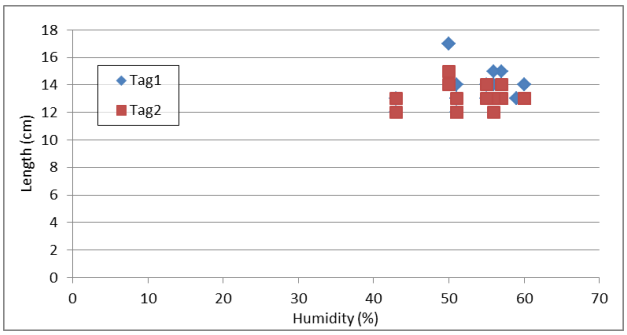

Figure 5. Measurement results of L_1

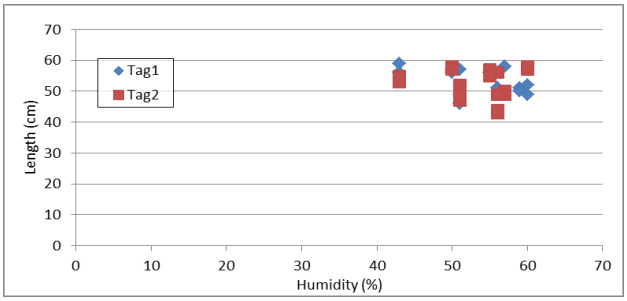

Figure 6. Measurement results of L_2

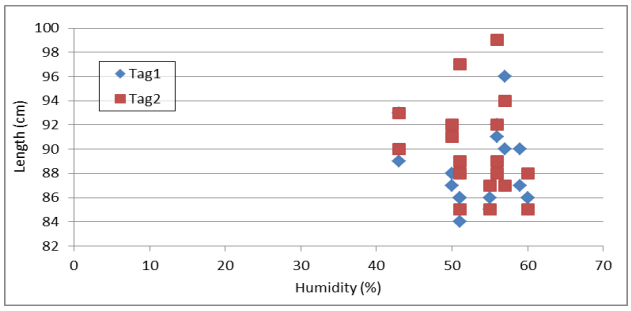

Figure 7. Measurement results of L_3

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B. *Angle between reader-electrode and tag*

The electrode of a touch tag reader and a touch tag is designed to generate an electric field on the surface of the body. Therefore, they have directional characteristics. We measured the received signal strength for a tag of which the direction increased 15 degrees from 0 to 315 degrees. The measurement conditions were as follows;

- There was fluid in the tube, or it was empty.
- Distances between the reader and a tag were 5 and 10 cm.

We used an intravenous bag filled with an isotonic sodium chloride solution.

The data were averaged over ten received signals. The measurement data are shown in Fig. 8. When there was fluid in the tube, the directional pattern was omni-directional. On the other hand, when there was not fluid in the tube, the received signal strength was stronger in the same or opposite direction between the reader-electrode and tag.

For detecting the removal of a drip infusion administration set, since there was fluid in a tube, a nurse did not have to focus on the attaching angle of Tag_2. On the other hand, L_1 has to be considered. However, when we measured L_1 (Fig. 5), the angle between the reader-electrode and tag varied every time. We believe the measurement data include this variation.

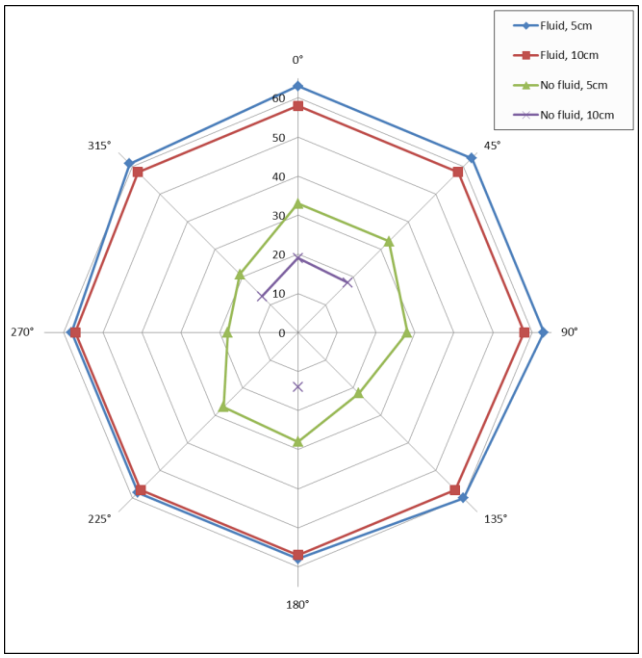

Figure 8. Directional characteristics of angle between reader-electrode and tag

C. *Touching tube between reader-electrode and tag*

An electric-field-type body area communication tag and reader-electrode generate an electric field between them and the earth via the human body when a person touches a tube between a reader-electrode and a tag, as shown in Fig. 9. Therefore, the received signal strength from a tag to the reader weaken when the person touches the tube. We measured how much the received signal strength was affected when someone touched the tube between the reader-electrode and tag, as shown in Fig. 9. The length between the reader-electrode and tag was 40 cm. There was fluid in the tube, which was attached to an arm with gummed tape. We used an intravenous bag filled with an isotonic sodium chloride solution. The measurement data are shown in Fig. 10. The received signal strengths for Tag_1 and Tag_2 were roughly the same and always steady when a tube was removed from an arm. On the other hand, the received signals for Tag_1 and Tag_2 varied by about 5 dB, when a participant touched the tube. There was not big difference between values for each tag. There was a 15 – 20 dB difference between when a participant touched the tube and did not. Since the signal strength at 25 cm for both tags was weak and varied like a sine-wave, we estimated there was a standing wave on the tube. However, we miss-estimated since the frequency of the touch tag was 3.2 MHz .

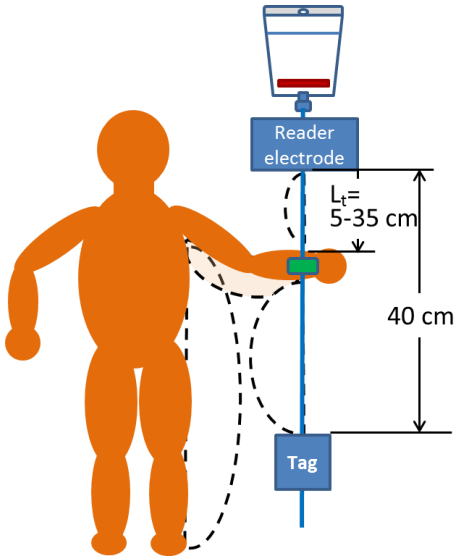

Figure 9. Image of electric-field between reader electrode, tag and earth via human

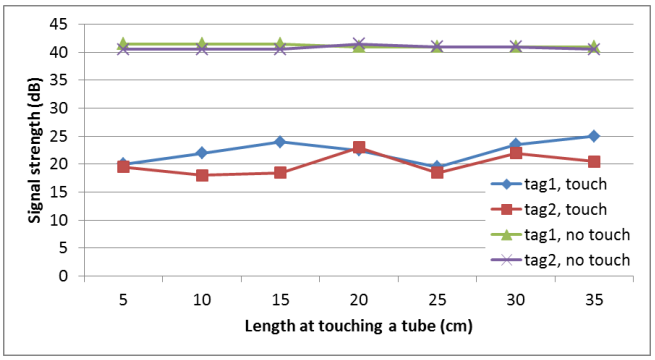

Figure 10. Effect of participant touching tube between reader and tag

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D. *Simultaneously reading two tags*

The Touch tag uses the semi-active method. The tag responds to a compellation of a reader to suppress electricity consumption of the battery in a tag. Therefore, the reader sometimes fails to read when two tags send a response at the same time. We measured the characteristics for reading two tags simultaneously. Tag_2 was attached to a tube 80 cm from the reader and L_r at which Tag_1 was attached changed from 20 to 70 cm, as shown in Fig. 11. We used an intravenous bag filled with an isotonic sodium chloride solution. The number of continuous miss-readings for each tag is shown in Fig. 12. In this figure, L_r is 20, 50 and 70 cm. The number of tag readings was 237 at 20 cm, 171 at 50 cm, and 253 at 70 cm. The values in Fig. 12 were corrected to normalize 100 readings.

A reader could read Tag_1 every time from L_r=20 to 40 cm. Since there is not a big difference between L_r=20 and 40 cm, the figure at 40 cm is not presented. The reason the reader could perfectly read Tag_1 must be due to the fact that the signal strength from Tag_1 is much stronger than that from Tag_2. Hence, when L_r was 70 cm, the number of continuous miss-readings for Tag_1 was the same as that for Tag_2. We believe the number of continuous miss-readings for Tag_1 and Tag_2 being completely the same must be a coincidence. When a reader does not read Tag_1, the tube must be empty, or the reader or tag is broken. The proposed system can instantly detect when a tube is empty.

No more than nine miss-readings occurred at every L_r. when the drip infusion administration set was removed, our system must detect it within at least of ten trying to read a tag after removing occurence. It is possible to detect such actions within 10 sec., when the reading period is 1 sec.

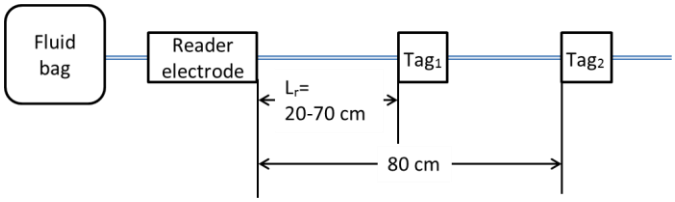
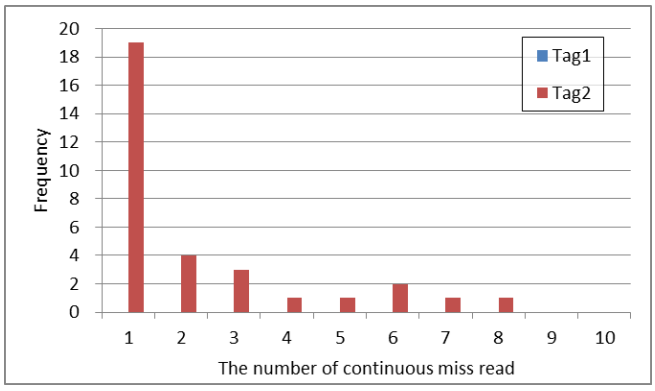
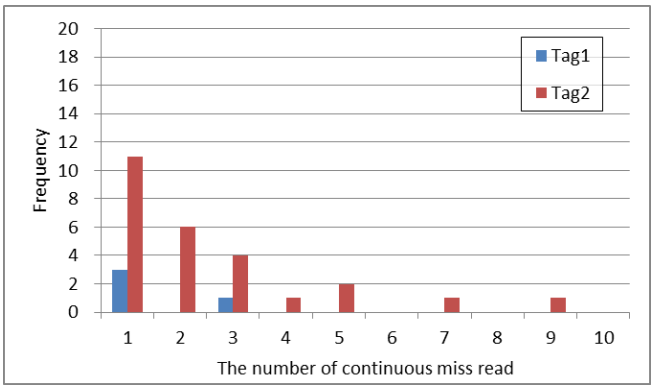


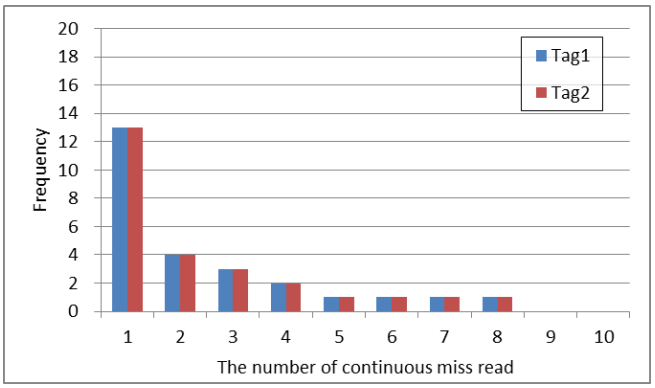
Figure.11 Positions at Tag 1 and Tag 2 for measuring characteristics for reading two tags simultaneousl



(a) Distance from reader L_r=20 cm



(b) Distance from reader L_r=50 cm



(c) Distance from reader L_r=70 cm

Figure 12. Miss-readings for two tags simultaneously

V. EXPERIMENTAL EVALUATION

From the results discussed in Section IV-A, we attached Tag_1 20 cm from the reader and Tag_2 70 cm from the reader, as shown in Fig. 3. The proposed system could detect an empty intravenous bag and a removal of a drip infusion administration set. We used an intravenous bag filled with an isotonic sodium chloride solution. The evaluations conditions were as follows.

- When bag was empty: was continuously unable to read Tag_1 10 times. We decided this condition to get certainty.
- Removal of the drip infusion administration set: instantly could read Tag_2. The reason we used this condition was that the reader may read Tag_2 ten times to detect if an administration set was removed, derived from the results in Fig.12 (a). This means the detection speed was very slow.

In our prototype system, an alert message for each incident was presented on a PC display. We determined if the bag was empty by pulling a tube off the bag instead of running fluid out of the bag. The reasons were that we did not have enough bags filled with the isotonic sodium chloride solution and it took too much time to measure. We did not connect a cannula to the tube. As a matter of course, we did not insert a cannula into a participant's arm. There were seven participants.

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We measured five times whether the proposed system could detect an empty bag and removal of a drip administration set or not for each participant. The proposed system could perfectly detect both types of incidents.

From the results in Fig. 12 (a), not being able to read 10 times is too severe for detecting if a bag is empty. In fact, the system presented an alert message for an empty bag being just after pulling the tube off the bag during the experiments. This judgment condition will have to be changed in a commercial system.

VI. CONCLUSION

We developed an intravenous drip infusion monitoring system using the Touch tags, a type of body area communication tag. This system can detect an empty infusion bag and removal of a drip infusion administration set by a patient. Unfortunately, this system cannot detect whether a cannula got off from the blood vessel or not, if the cannula is on or under the skin, because of the tube attached to the skin which prevents a reader to read the Tag_2 keeping on the skin.

One of the advantages of the proposed system is that installation is very easy. Installation only involves fastening an electrode of a reader and one or two tags to a tube. There also is no need to change an existing a drip infusion administration set. This system is applicable not only for standard gravity infusion administration sets but also a pump infusion administration sets.

We have already demonstrated this system at an exhibition for medical and welfare appliances and no miss-readings occurred. Since there is currently no monitoring system that can detect if a patient has removed his or her drip infusion administration set from his or her arm, our system was highly rated by participants such as nurses, doctors and medical equipment providers.

We could not evaluate the proposed system in a real-world situation for this research. Before evaluating the proposed system in such a situation, such as a hospital, we would like to change the design of the touch tag and electrode of the touch tag reader so that it can be easily attached to a tube, and transfer the decision function to a tag reader from a PC. We also plan to evaluate it in a real-world situation such as in a hospital.

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Are Mobile Devices Ready for Telementoring? A Protocol Design for Randomized Controlled Trials

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***Abstract*—This paper presents a study addressing the usability issues of relatively small touchscreen devices used as endpoints for telementoring. The trial is motivated by the need for systematic knowledge and user experiences on the use of mobile devices for remote supervision of surgeons. Having a stationary computer equipped with relatively large screen and using mouse as an input device in mind, we challenge mobile touchscreen gadgets in order to find out if the same (or sufficient) qualities of mentoring from the mentor's perspective are maintained. The presented study protocol exploits crossover randomized controlled trail design addressing the usability of mobile touchscreen devices for controlling a moving scene (video) and freehand sketching.**

Keywords-telementoring; mobile devices; usability; telestration; platform; RCT.

I. INTRODUCTION

Supervision of medical personnel over distance in order to improve patient outcome has been discussed from 1960s [1]. Technologies changed while the years passed by finally bringing the computational power, required for establishing telementoring session, to the devices surrounding us every day. One could call it the time when the dreams come true - the high availability of medical experts without any dedicated hardware became feasible. The employment of the ubiquitous technology to serve as a mediator between two remote parties pushed the domain to a new dimension. However, is there any proof that the new dimension ensures the same qualities of mentoring? Literature search identifies no interest in investigating the aspects of technology shift in clinical settings. It supports the claim that mobile touchscreen devices were considered and accepted as inevitable technological progress. But, is it the way to go? There are no doubts that mobile gadgets used in random settings are more likely to fail than stationaries, located in surgeon's office. Varying network coverage, battery constrains, interruptions by surrounding people and many other reasons create a fertile environment for unforeseen adverse events. However, not enough credit for the mentioned facts was given in publications so far.

Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) defines telementoring (or teleproctoring) as "a real-time and live interactive monitoring (evaluation) of technique(s) or procedure(s) of an applicant seeking privileges, or a surgeon seeking to certify or document his competence in a specific technique or procedure(s)" [2]. It is a process consisting of two interacting parties – a surgeon (mentee), performing an operation in the operating room and seeking for an advice from the domain expert (mentor) who is not available on site. The paper focuses on the infrastructure to facilitate the interaction between mentor and mentee.

The recent shift from stationary platforms to mobile touchscreen devices has not left telementoring systems behind. While bringing new features and possibilities, it brought new challenges as well. This paper summarizes the protocol for a Randomized Controlled Trial (RCT) aiming to compare different devices and find out whether they can be used as mentoring endpoints on mentor side. In the scope of the paper, platform refers to different hardware employed in a study, not looking into the differences of software platforms.

A telementoring system, developed in Norwegian Centre for Integrated Care and Telemedicine (NST) and deployed at University Hospital of North Norway (UNN), is used in the experiment. Telestration (drawing of freehand sketches over live video) is used in a combination with Video Conferencing (VC) system [3]. Notwithstanding the advantages of live video annotating in actual telementoring session, using the feature in the experiment allows us to compare mouse and touchscreen inputs for mentoring, extending the comparison of the platforms [4].

The paper is structured as follows: after a brief background on telementoring, the gap in research regarding the usability of touchscreen devices for telementoring is stated. Method section covers the study design and scenario, followed by the expected results. The paper is concluded by discussing the advantages of selecting the crossover study design and admitting potential biases and weaknesses.

II. RELATED WORK

Search for research comparing different input devices reported a low interest in the analyzed topic. Baldus and Patterson summarized the reported attempts to measure the differences in performing pointing and dragging actions in still scenes and office environment. Moreover, a comparison of mouse, touchscreen and touchpad was presented while controlling a still scene in a moving environment (vehicle) [5]. A gap in research dealing with usability of different

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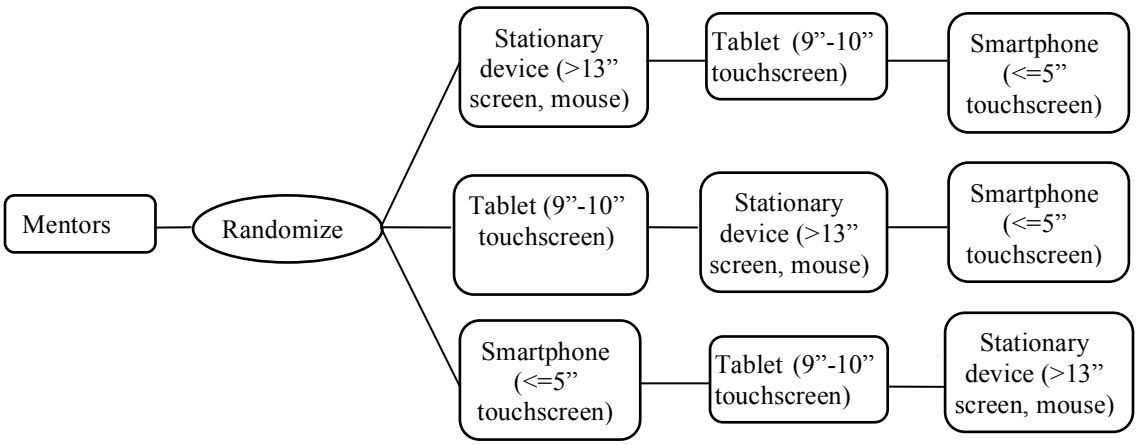

Figure 1. Schematic Trial Design

inputs while controlling a moving scene (video) and freehand hand sketching was identified.

III. METHOD

To produce sound proof on the analyzed topic, a RCT was constructed, employing the crossover study design (Figure 1). Instead of employing the common approach for the RCT (one type of intervention per arm), we let the participants experience all 3 devices in a randomized order. The absence of dependency on the interventions (devices) allows minimizing the number of participants as well as enables the reflection of preferences on the platforms [6]. Due to the high (and increasing) number of mentoring devices, generalization initiative was imposed. The pool of endpoints was divided into three groups based on the screen size, forming the arms of the study:

1. Screen size >13" laptop/desktop computer located in the office of the surgeon, representing stationary platforms. Mouse is used for annotating;
2. Touchscreen size 9"-10" Tablet computer, representing middle-sized mobile devices;
3. Touchscreen size <=5" Smartphone, representing small-sized mobile devices.

Even though the technologies allow using a wide selection of devices on each arm (which would be a typical scenario in a real case), the choice was limited in order to produce consistent and comparable results independent on different hardware on the same arm of RCT. The following devices were selected to represent the platforms:

1. Stationary device – Lenovo X220, I7, Windows 7 equipped with external monitor;
2. Tablet – Asus MeMO Pad, Full HD, Android 4.2;
3. Smartphone – Samsung Galaxy S4, Android 4.3.

Public wireless network infrastructure at the hospital is used for the experiment. All devices run the latest version of Google Chrome web browser as client software to run the telementoring service.

Surgeons at UNN are recruited to participate in the study. As the study employes an imitation of a mentoring session, the inclusion criteria for the participants are not emphasized. The properties of mentoring, observed on the mentee side are not taken into consideration in this study.

Every participant is asked to perform the same mentoring task on all three platforms in a randomized order. After each device, they fill in the questionaire, reflecting their experiences on the mentoring endpoint. Minimum washout period between testing different device is set to 3 days. Results are accumulated on a server side database for further analysis.

In the scope of this particular study, we collect the following data:

1. Mentor response time - duration between the initiation of mentoring session and mentor being present online (Figure 2);
2. Mentor's interaction with the device – coordinates of annotations, use of pause, resume and zoom functions are logged;
3. Final outcome of mentoring – video and overlaid annotations are recorded;
4. User experiences on every device are recorded by filling in an online questionnaire after each round.

The task for this particular experiment was defined as an imitated surgical mentoring session. The following scenario is being pursued: participants of the experiment are given the devices they will use for mentoring during a regular work day at the hospital. At random order and time, they are notified (by email and text messaging) to connect to the

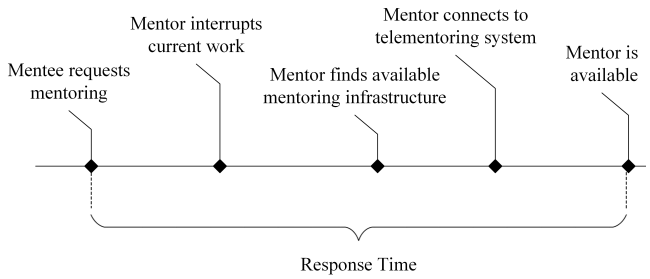

Figure 2. Mentor response time

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mentoring service and perform the task. After the mentor is connected, a short video, recorded during laparoscopic procedure, is broadcasted to the device. Participants are asked to identify and mark certain locations in the video (Figure 3).

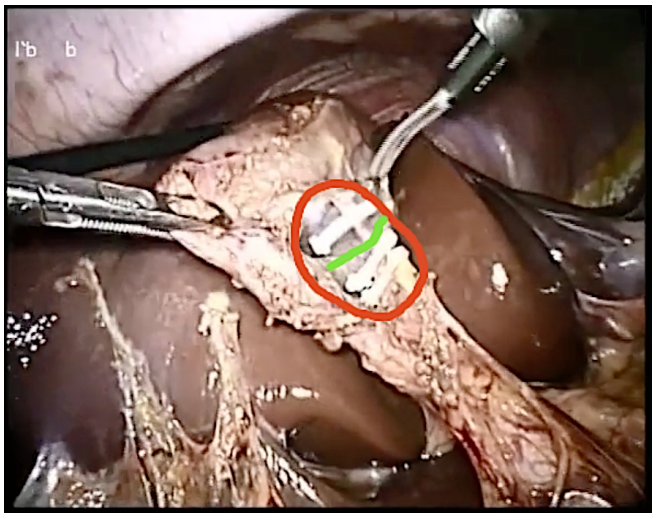

Figure 3. Telementoring task

A schematic view of the trial is depicted in Figure 4. Mentor side of the link facilitates all the functionality required to complete the mentoring task, while mentee part acts as an infrastructure for capturing the progress of the mentor for further analysis.

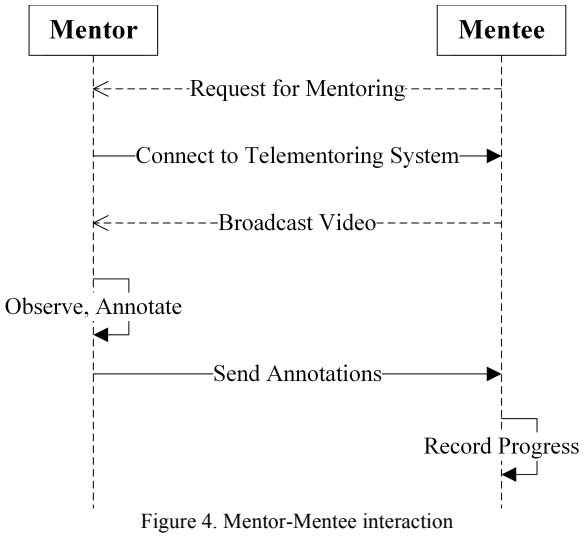

Figure 4. Mentor-Mentee interaction

IV. EXPECTED RESULTS

The paper presents a protocol for the oncoming study focusing on the usability of newly introduced devices. It is addressing the topic, which until now was considered to be natural due to the technological progress. While the move from stationary to mobile platforms is natural in many settings, medical domain deserves a more detailed outlook. The critical scenarios in the domain require in depth research before adopting the new devices.

The study, firstly, looks into the response time of the surgeon on call. It is defined as duration between mentee initiates request for supervision and mentor is connected to the system and is ready to assist (Figure 2). Due to the use of ubiquitous technologies, it should considerably decline, shortening the duration of the procedure (no need to get to predefined mentoring "station", mentor's office to supervise).

Secondly, we aim at studying whether the representation of surgical videos on small screens ensures the same (or sufficient) perception of the progress transmitted from the operating room. The complexity of projecting and perceiving a high resolution video on a small screen are obvious, however, having the technical advances of screen technology and the experience of surgical personnel in mind, the applicability of different sized endpoints for mentoring needs to be tested and evaluated.

Finally, we look at the way the user interacts with the device. In our case, it is either using mouse input or touchscreen in order to produce freehand annotations over live video stream. The study questions if different inputs can generate the same or comparable result, when it comes to accuracy. Is touchpad as good (or good enough) compared to mouse?

It is difficult to answer the postulated questions based on quantitative measurements. Differences of the devices (screen size, input using touchscreen of mouse) may have influence on mentoring process. However, we aim at answering whether the sufficient quality of mentoring is maintained while roaming among the platforms. Moreover, the trade between increasing availability of the domain experts due to the use of mobile ubiquitous devices and higher quality and accuracy, possibly ensured by stationary platforms, is also worth mentioning. No studies report what qualities of the mentoring process are considered sufficient. The results of the study contribute to defining the minimal set of requirements for surgical telementoring systems [7].

V. CONCLUSION AND FUTURE WORK

The paper presented a method to evaluate the use of mobile devices in health care settings with respect to the established technology (stationary platform – control arm in RCT design). It built the fundamentals for further investigations following the presented template. Imitated surgical telementoring session was selected for the case study. The identified gap of knowledge in literature regarding the use of different input devices in clinical settings encourages making the study protocol more generic for applying it in a wide range of settings. Generalization and reuse of the presented approach is straightforward. The main challenge is classification of high number of technological instances to representative clusters.

The selected crossover study design gives a comprehensive comparison of the different platforms. The main advantage of taking this approach is the fact that study could be performed including relatively low number of participants. As the order of using different devices is

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randomized, every mentor gets a chance to try every device. Eventually, the comparison of results can be performed at the level of individual (using results from testing stationary device as control), minimizing the bias caused by previous personal experience with the technologies or specific technical skills. It supplements the generalized comparison of the results among the different RCT arms [6].

The weak point of the study, possibly having some implications on final results, is the memory effect of the participants. They are asked to perform the same task three times, which will stimulate learning and may introduce bias. To minimize it, the order of the devices is randomized for every participant. In addition, washout periods after each step of the trial are imposed.

We also admit that the results of the study may be case and mentor experience dependent, especially when it comes to perceiving important internal body structures, represented on a small screen. However, this study emphasizes the use of the different devices and experiences of the users rather than mentoring process itself or how it is perceived on the mentee side. Therefore, the mentoring task performed on each device is kept simple to minimize the advantage of more experienced mentors. By including the mentors based on their experience it could improve the outcome; however, an objective measure of surgical skills is complicated due to the number of approaches [8]. In addition, differentiation based on experience would complicate the inclusion criteria for the participants, increasing the numbers of the surgeons to be recruited, as well as producing partitioned results.

Future work, first of all, concerns the analysis of the results from the current study. A series of trials, following the same study design, are planned in order to test and compare the properties of different platforms and video processing techniques used for remote mentoring. The results will form solid fundamentals for the development of telementoring systems.

ACKNOWLEDGEMENT

This research was funded by a Helse Nord grant (ID 5614/HST1025-11) to the Norwegian Centre of Integrated Care and Telemedicine (NST), University Hospital of North Norway (UNN). The study would not have been possible without the support of the Mobile Medical Mentor (M3) project team at NST and collaborators at UNN.

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Can Assessment of Health on an ICT-platform Improve Optimal Functionality and Lead to Participatory Care Among Older Adults?

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***Abstract*-The number of people reaching old age is increasing rapidly, challenging the society and healthcare to promote healthy and meaningful aging. There is, and has been for a few years, a big interest in collecting patient reported outcomes (PROs) as a base for clinical management. Information and Communication Technology (ICT) and assistive technology in elderly care increase and may facilitate the care of older adults as they are moved from nursing homes to private homes. An ICT-platform for reporting health issues with immediate access to self-care advice and direct communication with healthcare professionals has been developed. The overall aim of this project is to evaluate the effects of the interactive ICT-platform regarding optimal functionality and participatory care. The project will be conducted in three phases: development of the ICT-platform, feasibility evaluation and evaluation of effects. The platform is unique by integrating interactive components for direct clinical management and needs to be thoroughly evaluated before implementation in daily practice. It is hypothesized that, by using an interactive ICT-platform, it will promote participatory care and enhance the communication between older adults and their professional carers. The platform will be further developed, as well as tested in a full-scale study.**

Keywords-information and communication technology; older adults; patient-reported outcomes measure.

I. INTRODUCTION

In the Western world, the number of people reaching older age is increasing quite rapidly. Better living conditions such as improvements in nutrition, health and healthcare give a higher life expectancy and can be an explanation for the increase [1, 2]. The aging and elderly populations are placing demands on society, and especially on healthcare, to promote healthy and meaningful aging, according to the World Health Organization's (WHO) concept of "active ageing" [3].

This project will establish a new and modern technique where older adults can accurately report factors that influence their health and daily life, as well as systematically and rapidly communicate these to healthcare professionals caring for them. The older adults will also have access to instant self-care advice appropriate to the level of factors they report. This will enable problems to be identified earlier and necessary interventions to be initiated more promptly and enhance the communication between older adults and healthcare professionals, an approach to healthcare that is encouraged and needed today. We also intend to develop our theoretical model, The Participatory Care Model, which will support the implementation of a personalized interactive monitoring system for the older adults. The model focuses on allowing patients to take a participatory role in their own health and health care in an interaction with the healthcare providers i.e. being a member of the team.

II. BACKGROUND

A. Patient-reported outcomes measure

A Patient Reported Outcome Measure (PROM) includes all the aspects of a patient's health status, including disease symptoms, functioning and Health-Related Quality of Life (HRQoL), so that they are able to directly communicate these aspects to healthcare professionals without interpreting the patient's response by a caregiver or anyone else [4]. There is, and has been for a few years, a big interest in collecting PROM as a base for clinical management. Different ways have been used, for a long time pen and paper, but recently applications, such as touch screens and web-based systems, have been tested to collect PROMs [5]. Several studies in this area have shown that the use of PROM in clinical settings can simplify the detection of problems, facilitate communication between patients and clinicians, promote shared decision making and enhance patient satisfaction [6, 7].

B. Information and communication technology

Information and Communication Technology (ICT) friendly utilities and assistive technology in elderly care tend to increase since the care of older adults is not performed in nursing homes but in private homes instead [8]. The WHO defines E-health as "the transfer of health resources and health care by electronic means" [9] which makes the concept closely connected to activities on the Internet. A complement to E-health is assistive technology, which is defined by the WHO as a concept for any device or system that enables an individual to carry out an activity that otherwise would be very difficult or impossible to carry out [10]. ICT can help older adults to stay independent and healthy [11]. Overall, ICT combined with a strong governance structure and a fair performance management may result in integrated healthcare [12] and promotion of self-management [13]. Using ICT to enhance the care of and for older adults has several advantages such as providing information on how to manage occurring health issues [14]. The use of ICT has been shown to improve Quality of Life and feelings of

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being safe among older adults suffering from Alzheimer's Disease [15].

We did a scoping review to explore the concept optimal functionality in old age (people over 65 years of age in developed countries) and to integrate it with PROM. A total of 25 scientific articles were analysed. Three major themes were identified in the concept of optimal functionality in old age: self-related factors, body-related factors and external factors [16].

As far as we know, no studies regarding older adults using interactive ICT to promote optimal functionality have been made, thus showing that a knowledge gap can be seen in this area. The overall aim of this study is to evaluate the effects of an ICT- platform integrated with PROM to assess its effects on older adults' optimal functionality and participatory care.

The specific research questions are:

- How will the mobile phone system enable older adults to enhance engagement in self-care activity in order to improve health and optimal functionality?
- How feasible, user-friendly, and accepted is the ICT-platform from the elderly and health care professional´s perspective?
- How does the use of an interactive ICT-platform contribute to participatory care?

III. METHOD

The project will be conducted in three phases. Phase 1 includes development of the ICT-platform; Phase 2 evaluates the feasibility and acceptability of the ICT-platform; and Phase 3 concerns evaluation of effects.

A. Phase 1 The development of the ICT-platform

In a literature review and interviews with older adults and nurses involved in homecare, determination of the content of the questions in the application was explored (Fig 1).

1) Review of the literature, interviews with experts, older adults (n=12, >65 years of age) and healthcare professionals (n=8) were conducted to identify indicators that promote and/or counteract a good daily life and health. Fifteen areas were identified: fever, dizziness, difficulties eating, diarrhea, constipation, pain, fatigue, difficulties sleeping, worry, depression (sadness, dysphoria), difficulties performing daily activities indoors, difficulties performing activities outdoors, difficulties performing activities with others, experience of being safe, and experience of having a meaningful daily life of which 15 questions were created.

The structure of questions included in the application is based on standardized symptom and QoL questionnaires [17, 18] that is, the questions ask for occurrence, frequency, and distress level. For example "Do you experience constipation?" If the answer is yes, the older adult is asked how often it occurs, rated by frequency: never, sometimes, rather often, or very often. Furthermore, the older adult is asked how distressing the symptom is: not at all, a little, rather, or very much. The older adults will report at least three days during a week. A reminder message is sent if report has not been submitted. Besides the questions, the application contained evidence-based self-care advice related to the older adults´ concerns. Additionally, the application contains links to suggested relevant websites for more reading. The application also included a history graph in which the older adults could see how they reported their health status over a period of time (Fig. 1). A risk assessment model based on occurrence and frequency of the reported data was integrated into the application. Depending on the severity of the reported data, the nurse in charge could receive two sets of alarms to their work mobile phone (text messages), red and yellow alarms. Red was the more acute one meaning that the nurse would contact the older adult within a few hours; the yellow alarm meant that the nurse would contact the older adult the next day at the latest. This initiates an interaction whereby a nurse contacts the older adults for discuss their concerns.

With the help of a Swedish health management company (Health Navigator), the contents were implemented in a smart tablet as an application. The nurses in charge could also log into a web-interface and view the reports of the older adults on their computers (Fig. 2).

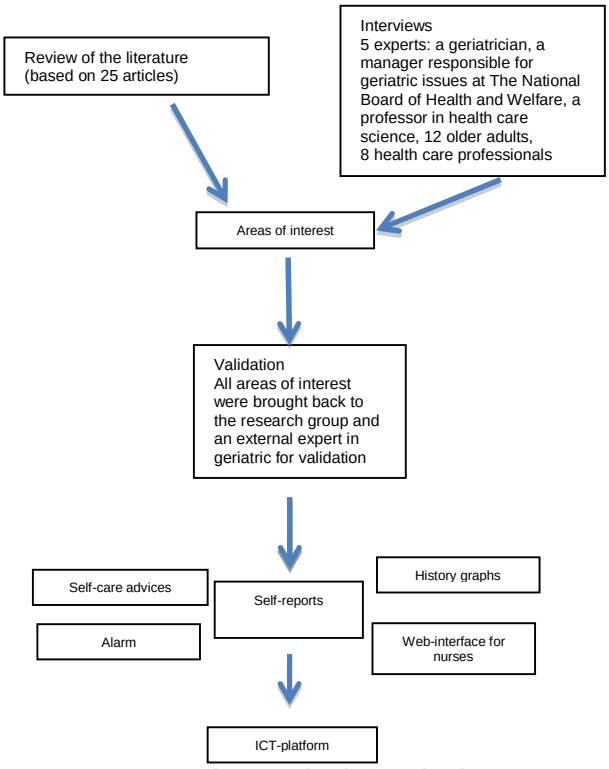

Figure 1. Outline over the platform development.

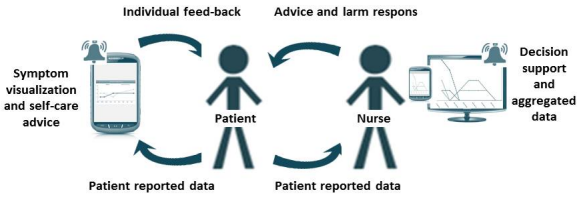

Figure 2. Illustration of the application chain.

B. *Phase 2 The evaluation of the feasibility and acceptability of the ICT-platform*

1) Eight older adults, ranging between the ages of 67 to 90 years of age, were included in the study. Inclusion criterions for participating in the study were being over 65 years of age, having a healthcare contact, being able to speak Swedish and also being able to read and write in Swedish. The older adults should be cognitively intact and/or not have an altered mental status. All the study participants were given a tablet (Nexus Google). The older adults tested the tablet with the ICT-application for a period of four weeks. Three nurses working with the older adults agreed to participate in the study. They were informed about the study, how the interactive system worked and how they would proceed when logging into the web-interface as well as view how the older adults have reported. The nurses were also informed on how they would handle the alarms coming into their work mobile phones.

2) Both older adults and nurses were asked to participate in individual interviews after the four weeks had passed. The older adults were interviewed individually and asked about the usability of the tablet and the application and the relevance of the questions in the health measure. The nurses were also interviewed about the relevance of the questions and about their experience of monitoring reports from the older adults and using the web-interface. Overall, the older adults found using the tablet and application as quite favourable. The application was perceived as user friendly, educational and fun to use. The questions were seen as relevant and clear but also as having a more broad perspective. The nurses in the study experienced the system as valuable and as something that could make the care with the older adults more accessible. One nurse expressed that this was a way of communicating with the older adults directly without any intermediaries.

C. *Phase 3 The evaluation of effects*

Next phase of this project will focus on testing the ICT-platform in a larger group of older adults (n=50) for a period of six months. There will also be a control group not using the ICT-platform to evaluate and determine its effects. Main outcomes are areas related to optimal functionality (for examples well-being, mental health, gut health, nutritional status, health literacy, coping ability, self-care and risk for falling). Interviews with the older adults and the health care professionals will also be conducted focusing on participatory care.

IV. CONCLUSION AND FUTURE WORK

The first phases of this study show that the interactive developed ICT-platform was feasible from both the older adults and their nurses' perspective. These studies will deepen our understanding of how older adults perceive participatory care, i.e., being a member of a team, when it came to the older adults' own healthcare plans, using PROM. Conclusively, the concept of optimal functionality can in the future enhance participatory care in the sense that the older adults know and are aware of their preferences. Possible effects will be measured in a larger sample of older adults and will enable us to improve and develop the ICT-platform, as well as develop opportunities to increase older adults´ optimal functionality.

ACKNOWLEDGMENT

We would like to thank all the participants in the pilot study and the nurses in the municipality who assisted us with support. We would also like to thank Health Navigator for the collaboration and technical support in this project.

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Lifestyle Log Based Blood Glucose Level Prediction for Outpatient Care

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***Abstract*—Treatment of diabetes mellitus is a crucial problem in modern health care. Surveys show that the currently used methods to estimate the required amount of insulin are quite inefficient in practice as they are based on experience and conjecture. This paper offers a new method to predict the glucose level of people with diabetes. The proposed approach combines two efficient models found in literature. The mixture of the methods tracks the blood sugar level considering nutrition, applied insulin and initial glucose level. According to our tests, the model gives satisfactory results with real patients both in inpatient and outpatient care.**

Keywords—Glucose-level tracking; eHealth; Glucose-Insulin system; Glucose absorption; Diabetes mellitus

I. INTRODUCTION

Diabetes mellitus is a metabolic disease that affects the whole society. It is a typical disease of the modern culture caused by obesity, the lack of physical activity and the changing of culinary culture. At the moment, this problem hits 3% of the population [1], but this number is increasing. The current predictions report that the number of people with diabetes can reach 5% within 2 decades [1]. This underlines the importance of diabetic lifestyle support.

The official classification separates diabetes mellitus into different types, according to clinical age [2]:

- Type 1 diabetes results from the lack of insulin production. The failure of insulin output is caused by an autoimmune destruction of beta-cells in the pancreas, which usually leads to absolute insulin deficiency. Patients diagnosed with Type 1 diabetes have to follow a strict diet and apply subcutaneous insulin by injection or insulin pump.
- Type 2 is the major form of diabetes as it accounts for 90% to 95% of all diagnosed patients (in the USA [3]). It is an insulin resistant stage caused by failure in insulin secretion. The treatment of these patients varies from lifestyle changing through diet and oral medications to subcutaneous insulin necessity.
- The third category contains special types, including gestational diabetes and other types caused by medications, infections, or other illnesses.

The remainder of the paper is structured as follows: Section II presents some related works and summarizes the prospects of this field. Section III contains the description of the proposed glucose level prediction system. Section IV includes the result of several tests with the model. Section V contains the discussion of the results. Finally, Section VI concludes the paper and outlines future work.

II. MOTIVATIONS AND LITERATURE OVERVIEW

The basic motivation of our efforts is to provide diabetics with a tool that they can use in everyday life to predict their blood glucose level. We focus on outpatients treated with insulin injection no matter having type 1, type 2 or other types of diabetes. These patients inject themselves with insulin considering meal, physical activity, sports and also the weather change. The main index to verify the patients' state is HbA_{1c} (Glycated hemoglobin). According to the recent surveys, these values are far from ideal in the case of several patients [4]. The gap does not seem big, but it can lead to serious complications; moreover a big variation of glucose levels endangers the life of a person with diabetes.

The whole metabolism can be divided into two parts, as Figure 1 shows. The first one is glucose absorption from meals and the second one is the glucose controlling system including insulin evolution.

From the aspect of glucose uptake, the absorption from intestine is the main factor, but the stomach has a significant role in the procedure as well. In connection with glucose control, there are many factors to take into account such as glucose uptake, inner insulin production, insulin input, etc. These factors are discussed later in this paper.

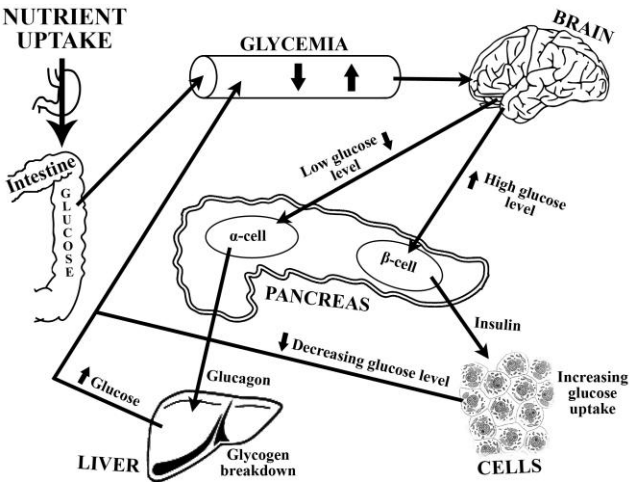

Figure 1. The process of metabolism

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TABLE I. THE PARAMETERS OF THE MODEL OF GLUCOSE ABSORPTION

Model of glucose absorption

Prefixes

Δ	The actual time interval ($\Delta t = t_{i+1} - t_i$).
m	The component is added by meal.
s	The component is in the stomach.
e	The component is ejected from the stomach into the intestine.
i	The component is in the intestine.
f	The component leaves the intestine as faeces.
a	The component is absorbed through the intestinal wall.

Variables

$Prot(t_i)$	The amount of proteins at time step t_i.
$Lip(t_i)$	The amount of lipids at time step t_i.
$Fibr(t_i)$	The amount of fibres at time step t_i.
$Monosac(t_i)$	The amount of monosaccharides at time step t_i.
$Starch_{GI}(t_i)$	The amount of starch with the given GI at time step t_i.
$Mass(t_i)$	The amount of nutriment at time step t_i.
$Water(t_i)$	The amount of water at time step t_i.
GER	Gastric emptying rate. [kJ/min]
$sVol$	Stomach volume. [ml]
τ_{wall}	Average time before the food obtains contact with the intestinal wall. [min]
τ_{GI}	The time of the starch breakdown process with glycemic index GI. [min]

Parameters

BM	The body mass in kg.
GI	The glycemic index of the food.

Constants

$CHOavail$	Bioavailability. The optimized value is 0.76.
$sVol_0$	Exponential constant for stomach emptying. The value is 225 ml.
SER	The specific emptying rate. The optimized value is 0.161.
IAR	Maximal intestinal absorption rate, the estimated value is 2.0 g/min.
$EnergyDens_j$	The energy density is 17kJ/g for proteins, starch and monosaccharide, 0kJ/g for fibres and 39 kJ/g for lipids.
τ_{fibr}	Exponential time constant for excretion set to 180 min.
$\tau_{wall\,0}$	Set to 1000 min.
τ_{100}	Time constant for starch breakdown with GI 100. The optimized value is 28.0 min.
α	Parameter relating τ_{GI} to the glycemic index. The optimized value is 0.0125.

TABLE II. THE PARAMETERS OF THE GLUCOSE CONTROL MODEL

Glucose control model

Variables

$G(t)$	Plasma glycemia. [mM = mmol/l]
$I(t)$	Insulinemia. [pM = pmol/l]
$S_1(t)$	The insulin mass in the accessible subcutaneous depot. [pmol/$kgBW$]
$S_2(t)$	The insulin mass in the non-accessible subcutaneous depot. [pmol/$kgBW$]
$f(G)$	Pancreas Insulin Delivery Rate.

Parameters

K_{xgi}	Rate of glucose uptake by insulin-dependent tissues per pM. [1/(min ∗ pM)]
T_{gh}	Net balance between hepatic glucose output and insulin-independent zero-order glucose uptake (by brain). [mmol/(min ∗ $kgBW$)]
V_G	Distribution volume for glucose. [L/$kgBW$]
K_{xi}	Apparent first-order disappearance rate for insulin. [1/min]
T_{iGmax}	The maximal rate of second-phase insulin release. [pmol/(min ∗ $kgBW$)]
V_i	Distribution volume for insulin. [L/$kgBW$]
τ_g	The delay with which the pancreas varies secondary insulin release in response to varying plasma glucose concentrations. [min]
$t_{max\,,I}$	Time-to-maximum insulin absorption. [min]
$u(t)$	Subcutaneous insulin delivery rate. [pM/min]
$kgBW$	The weight of the patient. [kg]
G^*	The glycemia at which the insulin release is half of its maximal rate. [mM]
γ	The progressivity with which the pancreas reacts to circulating glucose concentrations.

Our model uses a combination of two existing models for nutriment absorption and glucose control.

There are methods for measuring glucose absorption [5] from meals such as the Diabetes Advisory System - DIAS [6]. Lots of models build upon this system though its base is only a simple one-compartment model. In order to create a more precise algorithm, other methods use glycemic indices (GI) [7] allowing mixed meals input such as the two-compartment model from Arleth et al. [8]. These methods provide a simulation closer to reality.

Beside glucose absorption, the evolution of insulin is the other main factor in tracking glycemia. There are even more methods in this field [9] starting with the so called minimal model which is still used in practice since it is a relatively simple method based on ordinary differential equations [10]. Several methods are the approximations of this model, e.g., [11]. The minimal model has low number of parameters, hence a limited predictive power. This problem is solved in more sophisticated methods, using differential equations. These approaches might use integro-differential equations [12], partial differential equations [13] or delay differential equations [14]. Such solutions as the latter support

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subcutaneous insulin depot, create better representation of the Insulin Delivery Rate (IDR), etc.

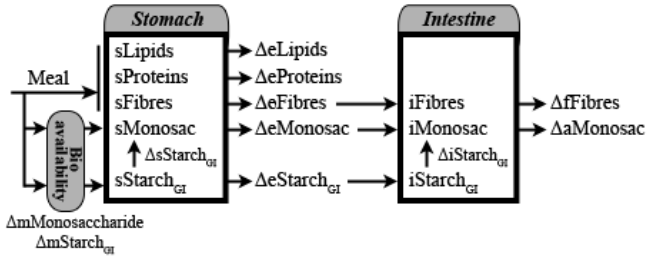

Figure 2. The process of absorption from mixed meals

III. THE PROPOSED METHOD

As mentioned before, our method combines two existing, state-of-the-art models to simulate plasma glycemia by influences of meals and insulin uptake. We chose these models because they have a realistic, comprehensive set of parameters capable of simulating a real-life outpatient as well.

A. Glucose Absorption From Meals

A two-compartment method [8, 15] is used to model the effect of nutrition on blood glucose level. The model proposed by Arleth T. et al. divides the digestion into two segments, as seen in Figure 2. The food first arrives to the stomach compartment followed by emptying into the small intestine and later into the large intestine. The absorption of the monosaccharide happens in the intestinal part; the remaining mass is ejected as faeces.

Simpler methods, like DIAS, operate with carbohydrate as input and take some components (e.g., lipids, proteins, starch) out of consideration. In contrast, our model takes protein, lipid, monosaccharide, fibre and starch as input, each one having its own effect during the absorption. In addition, the method can deal with mixed meals by using GI. Moreover, digestion overlap is handled properly as well.

The whole process is based on mass balance equations [15]. The equations for the stomach compartment are as follows:

$$sProt(t_{i+1}) = sProt(t_i) + \Delta mProt(t_i) - \Delta eProt(t_i) \quad (1)$$

$$sLip(t_{i+1}) = sLip(t_i) + \Delta mLip(t_i) - \Delta eLip(t_i) \quad (2)$$

$$sFibr(t_{i+1}) = sFibr(t_i) + \Delta mFibr(t_i) - \Delta eFibr(t_i) \quad (3)$$

$$\begin{aligned} sMonosac(t_{i+1}) = {} & sMonosac(t_i) + \Delta mMonosac(t_i) \\ & * CHOavail - \Delta eMonosac(t_i) \\ & + \sum_{GI} \Delta sStarch_{GI}(t_i) \end{aligned} \quad (4)$$

$$\begin{aligned} sStarch_{GI}(t_{i+1}) = {} & sStarch_{GI}(t_i) + \Delta mStarch_{GI}(t_i) \\ & * CHOavail - \Delta eStarch_{GI}(t_i) \\ & - \Delta sStarch_{GI}(t_i) \end{aligned} \quad (5)$$

The rate of ejection from stomach to intestine is measured by the gastric emptying rate (GER) [15]:

$$GER = SER * BM * \left(\frac{BM}{70}\right)^{0,425} * (1 - e^{sVol/sVol0}) \quad (6)$$

$$\begin{aligned} sVol = {} & \left(sProt + sLip + sFibr + \sum_{GI} sStarch_{GI}\right) * 3 \\ & + sMonosac * 18 \end{aligned} \quad (7)$$

The ejection from stomach to intestine is calculated considering the energy of the food components ($Energy_j$) using GER. The following equations [15] determine the actual ejections for each state variable ($StateVar_i$):

$$\Delta eStateVar_i = \Delta t * sStateVar_i * \frac{GER}{sTotalEnergy} \quad (8)$$

$$sTotalEnergy = \sum_j sEnergy_j \quad (9)$$

$$sEnergy_j = sStateVar_j * EnergyDens_j \quad (10)$$

The next compartment is the intestine, where proteins and lipids do not play a role anymore. The absorption of monosaccharides (15) happens here.

$$iFibr(t_{i+1}) = iFibr(t_i) + \Delta eFibr(t_i) - \Delta fFibr(t_i) \quad (11)$$

$$\Delta fFibr(t_i) = iFibr(t_i) * (1 - e^{-\Delta t/\tau_{fibr}}) \quad (12)$$

$$\begin{aligned} iMonosac(t_{i+1}) = {} & iMonosac(t_i) + \Delta eMonosac(t_i) \\ & - \Delta aMonosac(t_i) \\ & + \sum_{GI} \Delta iStarch_{GI}(t_i) \end{aligned} \quad (13)$$

$$\begin{aligned} iStarch_{GI}(t_{i+1}) = {} & iStarch_{GI}(t_i) + \Delta eStarch_{GI}(t_i) \\ & - \Delta iStarch_{GI}(t_i) \end{aligned} \quad (14)$$

$$\begin{aligned} \Delta aMonosac(t_i) = \min\Big\{ & iMonosac(t_i) \\ & * \left(1 - e^{-\frac{\Delta t}{\tau_{wall}}}\right), (IAR * \Delta t)\Big\} \end{aligned} \quad (15)$$

$$\tau_{wall} = \tau_{wall\,0} * iFibr/iMass \quad (16)$$

$$\begin{aligned} iMass(t_i) = {} & iMonosac(t_i) + \sum_{GI} \Delta iStarch_{GI}(t_i) \\ & + iWater(t_i) + iFibr \end{aligned} \quad (17)$$

$$iWater(t_i) = iMonosac(t_i) * 37 \quad (18)$$

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The following equations [15] calculate the breakdown of starch into monosaccharides:

$$\Delta sStarch_{GI}(t_i) = sStarch_{GI}(t_i) * (1 - e^{-\Delta t/\tau_{GI}}) \quad (19)$$

$$\Delta iStarch_{GI}(t_i) = iStarch_{GI}(t_i) * (1 - e^{-\Delta t/\tau_{GI}}) \quad (20)$$

$$\tau_{GI} = \tau_{100}[1 + \alpha * (100 - GI)] \quad (21)$$

The definition of the parameters is given in Table I. For further details of the model see [15].

B. Glucose Control System

A sophisticated glucose control system model was chosen using Delay Differential Equations (DDE), proposed by P. Palumbo et al. [14, 16]. This model has several parameters to support both type 1 and type 2 diabetics (see Table II). It is also possible to use insulin pump or subcutaneous insulin injections as input. The method uses two subcutaneous depots (accessible and not-accessible) to simulate subcutaneous insulin absorption. The main equations [16] are:

$$\frac{dG}{dt} = -K_{xgi}\,G(t)I(t) + \frac{T_{GH}}{V_G} \quad (22)$$

$$\frac{dI}{dt} = -K_{xi}\,I(t) + \frac{T_{iGmax}}{V_I} f\big(G(t - \tau_G)\big) + \frac{1}{V_I t_{max\,,I}} S_2(t) \quad (23)$$

$$\frac{dS_2}{dt} = \frac{1}{t_{max\,,I}} S_1(t) - \frac{1}{t_{max\,,I}} S_2(t) \quad (24)$$

$$\frac{dS_I}{dt} = -\frac{1}{t_{max\,,I}} S_1(t) - u(t) \quad (25)$$

The Insulin Delivery Rate (IDR) is modeled by the nonlinear $f(G)$ function [16]:

$$f(G) = -\frac{\left(\frac{G}{G^*}\right)^{\gamma}}{1 + \left(\frac{G}{G^*}\right)^{\gamma}} \quad (26)$$

IV. RESULTS

We implemented the combined model in a prototype and checked the correctness of our implementation by comparing its results to those published for a virtual patient in the original paper [16]. The parameters of the model were taken from the literature [17], from an intravenous glucose tolerance test experiment on an obese patient, slightly changed to simulate Type 2 diabetes mellitus (see Table III). The results showed good correlation to those published.

In the next step, we validated this model on outpatient data. Two persons with diabetes mellitus were examined. The first test involved a woman with Type 2 diabetes, while the second patient was a Type 1 diabetic man (see Table IV). Both patients are treated with subcutaneous insulin injection.

TABLE III. THE PRAMETERS OF THE VIRTUAL PATIENT WITH TYPE 2 DIABETES MELLITUS

Parameter	Value
K_{xgi}	3.11*10^{-5}
T_{gh}	0.003
V_G	0.187
K_{xi}	1.211*10^{-2}
V_i	0.25
T_{iGmax}	0.236
τ_g	24
$t_{max\,,I}$	55
G^*	9
γ	3.205

TABLE IV. THE PARAMETERS OF THE OUTPATIENTS WITH SUBCUTANEOUS INSULIN TREATMENT

Patient *A* with Type 2 diabetes mellitus		**Patient *B* with Type 1 diabetes mellitus**	
Birth date	1952	Birth date	1993
Gender	female	Gender	male
Height	156 cm	Height	196 cm
Weight	78 kg	Weight	83 kg
Applied insulin	Lispro	Applied insulin	Glulisine
Peak	60	Peak	55
Quantity/Unit	6000 pmol	Quantity/Unit	6000 pmol

The tests on both persons were executed with the same parameters as seen in Table III except T_{iGmax} , which is set to 0.1. The patients used similar types of insulin with the same quantity per unit indicator. On the whole, a reliable comparison can be made between the outcomes.

The first diabetic patient, outpatient A, was treated as inpatient to adjust her inordinate glycemia. Medication, glucose readings and meals were logged during 6 days including 15 meals and 45 glucose level measurements by ordinary blood sugar meter. The available meal log may contain inaccurate values if the patient consumed other meals except those offered as the controlled menu.

In the case of outpatient B, a controlled experiment was conducted during 3 days with 13 meals. The blood sugar level was monitored by a Medtronic Guardian Real-Time Continuous Glucose Monitoring (CGM) System, measuring the actual value every 5 minutes. The food portions were measured properly with scale and the time of meal and insulin input was logged correctly with minimum possibility of false values, using an android-based nutrition logger application [18].

Two different kinds of tests were made with each patient. The first simulation used meal wise records, i.e. the meals were treated as separate tests. Each test was run with zero startup blood insulin level and no running glucose absorption. The second test used a whole day's data with zero startup blood insulin level in the morning. During this test, the absorption of the insulin and the glucose from food could be in progress at the next meal as well.

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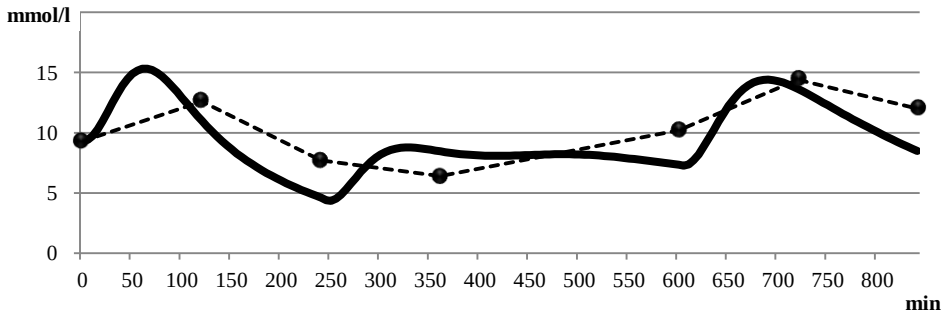

Figure 3. The fifth day of the meal wise test of patient A (solid line – model estimations, dashed line – measured values)

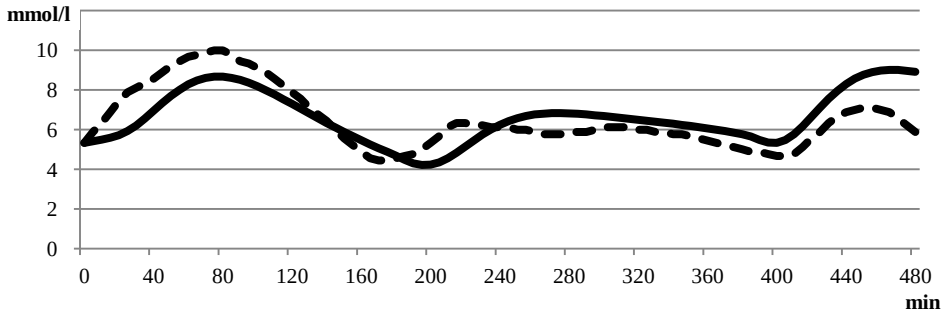

Figure 4. The first eight hours of the whole third day of patient B (solid line – model estimations, dashed line – measured values)

The results (see Table V and Table VI) prove that the whole day test gives better tracking as it takes more factors into account. The model copes with insulin absorption and digestion overlap which means around 5% improvement regarding the rate of deflection. The average deflection decreased with 0.45 mmol/l.

Comparing the two patients (see Figure 3 and Figure 4), there is more than 1 mmol/l decrease in average deflection if the experiment is properly logged. There is also more than 10% increase in the significant fields of rate of deflection (<3mmol/l).

TABLE V. COMPARISON BETWEEN THE TWO TESTS WITH PATIENT A

Patient A – 15 meals		**Meal wise**	**Whole day**
Average deflection		4,0 mmol/l	3,55 mmol/l
Rate of deflection	< 3 mmol/l	50 %	57 %
	< 5 mmol/l	68 %	79 %
	< 8 mmol/l	93 %	93 %

TABLE VI. COMPARISON BETWEEN THE TWO TESTS WITH PATIENT B

Patient B – 13 meals		**Meal wise**	**Whole day**
Average deflection		2,99 mmol/l	2,35 mmol/l
Rate of deflection	< 3 mmol/l	65 %	69 %
	< 5 mmol/l	76 %	81 %
	< 8 mmol/l	94 %	100 %

V. DISCUSSION OF RESULTS

The large differences between the prediction and the measured values that we experienced for patient A were most probably due to the poor quality of the dietary log. Also, it is harder to assess the performance of the model using only point-wise measurement data. For patient B, the error was fairly low (below 4 mmol/l) in the first hours (Fig. 4) and since we can re-start the model after the meals, the error calculated for the whole day in Table VI is over-pessimistic. However, the 4 mmol/l error is still fairly large, so relying solely on the model we could not exclude emergency situations (i.e. hypoglycemia) in a real life application. For better results, more efficient parameter training is needed.

The meal wise test with patient A also shows (see Figure 3) that using an ordinary blood sugar meter can lead to considerable errors in blood sugar level estimation. The patient measured a high value at 120 minutes, but the model shows even higher values between the two real-life measurements (0 min and 120 min). In this situation the gap is small, but there could be bigger differences as well. The frequent presence of these situations can lead to higher HbA_{1c} values.

Long-term model based predictions are in general less unreliable as the deviations accumulate. However, the proposed approach gives satisfactory results for short time prediction, which is the main demand to estimate the required amount of insulin in outpatient care.

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VI. CONCLUSION AND FUTURE WORK

The paper presented a combined model for the short time prediction of the blood glucose level, based on the dietary log of type I and type II diabetic patients. The results are satisfactory even without any model training.

Further research is needed for

- training the model to support personal variations in model parameters
- extending the model to use also other physiological data available like physical activity and stress.

Our aim is to decrease the average error under 1 mmol/l, which is a sufficient margin of error considering that the currently used real measurements have similar margin of error. The model is currently being further evaluated in a clinical study involving 20 rehabilitation patients, as an add-on module to the Lavinia lifestyle mirror [18].

ACKNOWLEDGEMENT

The work presented was supported by the European Union and co-funded by the European Social Fund, project title: “Telemedicine-focused research activities in the field of Mathematics, Informatics and Medical Sciences”, project number: TÁMOP-4.2.2.A-11/1/KONV-2012-0073.

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Let us Get Real! An Integrated Approach for Virtual Coaching and Real-time Activity Monitoring in Lifestyle Change Support Systems

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***Abstract*—There is a fast growing number of eHealth systems aiming at supporting a healthy lifestyle. Tailored lifestyle coaching services offer individual users access to web portals where they can communicate about a growing number of ingredients of everyday life concern: physical activity, nutrition, medication, mood, sleep. Mobile technology in combination with body worn sensors support user's awareness of their physical condition and lifestyle. Despite the large number of available lifestyle interventions and pilot trials, only very few are successfully transferred into the real health care practice. This paper presents new insights and recommendations for the design of lifestyle support systems with personalized virtual coaching based on two user studies. The first study focuses on the mobile physical activity coaching for diabetes patients and office workers. The second study summarizes the persuasive factors on attitudes of high-risk adolescents towards a virtual coach in mobile eHealth applications and social media. We present a new approach that integrates an animated digital coach in an activity monitoring lifestyle change support system.**

Keywords-Mobile Activity Monitoring, Personalized eHealth; Persuasive Feedback, Usability; Virtual Coaching; Behavior Change; Lifestyle Interventions

I. INTRODUCTION

Recent massive media attention to the obesity epidemic worldwide and growing number of patients with chronic diseases raises the demand for encouraging physical activity and raising health awareness [1]. Next to classical web-based interventions, eHealth behavior change support systems for healthy lifestyle promotion aim to motivate patients to healthy behavior change [2] [3] [4]. Some systems become proactive and provide real time information and feedback to their users based on data gathered through various sensors and personal devices [5] [6].

Despite the large number of existing lifestyle interventions and pilot trials, only very few are successfully transferred into the real healthcare practice [7] [8]. Users often have problems to navigate through the system, they get lost or they do not find the information they are looking for [9]. Low usability and lack of transparency on the reliabilty and trustworthiness of the information are just a few examples of the major barriers for successful implementation [4] [7] [8]. There is also a lack of standardization for interoperability between various parts of the systems and a lack of connection between the feedback, the actual usage patterns and the task a user is involved in [10]. These problems are often caused by a design that does not meet the actual needs of the target users while using the system and a lack of connection with offline, daily, activities. A holistic design approach for eHealth intervention development which we use in our research has proven to contribute in overcoming these barriers [8].

This paper presents new insights and recommendations for the design of lifestyle support systems with personalized virtual coaching based on two user studies. The studies represent different perspectives on eHealth systems. The first study has a Human Computer Interaction (HCI) perspective and focuses on the use of a virtual animated character in a multi-device mobile physical activity coaching system for diabetes patients and office workers. It was performed at the Human Media Interaction group of the Computer Science Department at the University of Twente. It was carried out in the context of the EU funded Artemis project Smarcos, led by Nokia, VTT and Philips. The overall theme of this ICT project is the inter-usability of multi-device multi-sensor systems. The second study summarizes the persuasive factors and attitudes of high-risk adolescents towards virtual coach in mobile health applications and social media. This study was performed at the Center for eHealth Research and Disease Management, Psychology Health and Technology group of the Behavioral Sciences Department at the same university.

In the next section, we first highlight findings from related work on physical activity monitoring, virtual coaching and mobile eHealth applications for lifestyle support. After that, we present a new approach for a multi-device coaching system based on the outcomes of two user studies on virtual coaching for lifestyle support. The first study describes results of the user evaluation of the mobile physical activity coaching system for office workers and diabetes patients. The second study focuses on persuasive factors and attitudes of high-risk adolescents towards virtual coaching, social media and mobile apps for sexual health promotion. Summarizing the main outcomes, we then present recommendations for the design of lifestyle support systems with personalized virtual coaching. Finally, we present the main conclusions and discuss future work.

II. RELATED WORK

There have been various attempts in categorizing eHealth technology [5] [8] [11] [12] [13]. In this paper, we focus

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on monitoring physical activity and health related parameters (blood pressure, weight) in lifestyle interventions for preventive professional care support. A categorization is based on the type of platform that the eHealth technology is realized on: stand alone devices; integrated web-based interventions and personal mobile devices; or a combination of various devices to monitor online and offline activities of a target user. We will highlight the multi-device approach which falls into the category.

A. Physical Activity Monitoring and Coaching

Wearable health technology, such as activity sensors, is often used as a surveillance tool to objectively assess physical activity patterns [6] [14] [15]. They provide an inexpensive, accurate, and reliable objective measure of physical activity by counting the number of steps taken per day, enabling the accumulative measurement of occupational, leisure time, and household activity, along with activity required for everyday transportation. In addition to their use as a measurement tool, activity sensors are also a popular motivational tool. The ability of an individual to receive immediate feedback on their accumulated step count is an important feature of the motivational aspect of the applications using activity sensors data [15]. A comparative study suggests that the greatest increase in step counts occurs when participants are requested to wear an unsealed sensor and record their step counts real time.

Engaging patients requires user friendly interfaces and user friendly interaction with the systems. Patients often have to cope with various physiological measurements instruments (either active or passive): blood pressure, blood sugar and weight. Willingness to measure these parameters strongly depends on the complexity of the user interface of the measuring device or sensor, as well as the data transfer process [16].

Based on an extensive literature study, H. op den Akker et al. [17] identified six key areas for research to improve digital coaching for physical activity by tailoring to the individual user. Two of them are of interest here: advanced Human-Computer Interaction (HCI) and pervasive coaching. To increase perceived intelligence of a coaching system, a virtual coach offers an interesting opportunity as an interface metaphor. Bickmore et al. [2] studied the effects of interventions for multiple health behaviors using conversational agents as a coaching system. This study showed that virtual conversational agent as a coach can have a positive effect on perceived relationship of a patient with an eHealth system.

Computer tailoring and personalized eHealth offer great potential for motivating people by providing personal information and feedback [18]. Characteristics of an intervention, such as enabling personal goal setting and providing tailored feedback are thought to be among the important factors related to of use of and exposure to lifestyle support systems. Next to tailoring, personal feedback needs to be dynamic to provide new information and real time feedback on the daily activities. The user study of Consolvo et al. [14] reports that negative feedback or paternalism has a negative impact on the users.

B. Mobile eHealth and Coaching

Mobile devices providing personalized feedback to influence physical activity behavior are gaining more and more popularity [19]. There are few examples of mobile health applications (apps) specific for behavior change and physical activity support [5] [19] [20]. Despite a huge range of health-related apps on the market, there is little in depth research on user experiences and views on a wide range of features that apps can provide.

Fanning et al. [19] present extensive review on efficacy of mobile devices in the physical activity and recommendations for implementation. This study concludes that mobile technology applied in behavior change interventions is an effective tool for increasing physical activity.

User studies in mobile health research are rarely performed with young adults, though adolescents are forerunners of mobile technology. Dennison et al. [20] present the findings of a focus group study with students on the use of mobile apps to support a healthy lifestyle, the attitude of adolescents on the usefulness of various features of such apps. The results suggest that the most important factors influencing the use and uptake of mobile apps are accuracy, legitimacy, security, effort required, and immediate effects on mood. Another features that young adults valued were ability to record and track own behavior and goals, as well as the ability to receive advice and real time information. Interesting finding from this study is that context-sensing capabilities of mobile apps and social media features were perceived as unnecessary.

Consolvo et al. [14] reports a long-term user evaluation with the UbiFit system which aims at raising individual awareness on physical activity level. The results show that glanceable representations of information on personal, mobile displays can stimulate the person to do more exercises. These findings are consistent with another study [21].

C. Serious Gaming for Lifestyle Support

New forms of entertainment media such as serious gaming are used for promoting healthy lifestyle [22]. Serious gaming and interactive gaming elements embedded in eHealth technology offer great potential in innovative opportunities for engaging adolescents and other patients in interventions promoting healthy nutrition habits and physical activity changes that can contribute to obesity prevention and healthier lifestyle [22].

III. User evaluations of a mobile animated activity coaching system

As humans interact with many different devices during the day, cross media systems offer the opportunity for the activity coach to travel with the user across those devices. Depending on the needs and context of the user, coaching can thus be provided on the most suitable device (e.g., smartphone, PC, smart television) [23].

A. Digitial Coaching Architectures

A multi-device digital coaching can have a more *centralized* or a more *decentralized* architecture. The main difference is in the measure of autonomy of the mobile coaching application. The Continuous Care & Coaching Platform (C3PO), developed at Roessingh Research and Development (RRD) in the Netherlands, enables continuous remote monitoring of elderly patients and patients with chronic disorders [24]. In

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the C3PO platform, there is only one device with which the patients users interact, the smartphone. The care givers can view patient data that is uploaded to a server. An activity monitoring and feedback system was designed to guide patients in reaching a healthy daily activity pattern. Objective daily activity is assessed using an inertial sensor node that captures and communicates wireless. The sensor can store large amount of data and send the data over Bluetooth to a PDA (an Android based HTC Desire) where further processing and communication to the patient is handled. The users receive feedback on their smartphone at scheduled times or if their activity level calls for this. In this *decentralized* architecture the coaching rules reside on the client-side mobile. In contrast to this, in the *centralized* architecture of the Smarcos platform the coaching rules reside on the server (see Figure 1 for an overview). Based on server side stored sensor data or on fixed times, the server sends a message to the client, who can receive the message on the device of his own choice. To upload activity data the user has to connect his sensor to the internet.

In the Smarcos system, feedback is a reminder to connect the activity monitor to upload data, a motivating message when activity is less than the target or an overview of daily, weekly and monthly scores. A drawback of the Smarcos system compared to the RRD system is that feedback is not real-time. The RRD system allows immediate feedback based on recent data collected from the sensor. A call for urgent medication intake (e.g., in a diabetes I medication coach) requires real-time feedback. In the Smarcos system, scores are presented as percentages of a user set target score and in terms of kCal. The user can get these activity overviews on his mobile device app, as well as via a web portal.

B. User Evaluations: Animated Virtual Coach

User evaluations were performed throughout the development of the Smarcos coaching system [23] for physical activity support and diabetes II patients. We performed short user evaluation with diabetes patients and office workers. We focused on the graphical user interface, on the interaction and on personal feedback in particular. We looked at timing, content, modality and presentation format. We are particularly interested in the application of animated virtual humans and multi-modal natural dialog as a means for interaction between the user and the digital coach. At the Human Media Interaction group we developed mobile technology for responsive animated Embodied Conversational Agents (ECAs) [26] for the presentation of feedback on a mobile app. The system can produce ECA behaviors (eye blink, eye gaze, head movements, lip sync with natural speech and facial expressions) specified in the Behavior Markup Language (BML) [27]. In the centralized Smarcos system the server sends a feedback message to a client containing a BML specification. The BML contains the text to be pronounced by the ECA as well as the non-verbal embodiments.

The mobile animated virtual coach was used in several short user experiments with the Smarcos architecture, as well as with the decentralized coaching platform developed at Roessing Research and Development [23].

In a 'long-term' user evaluation with the Smarcos system office workers (forty-one completed the evaluation, aged 21-57 years) were randomly assigned to one of three groups: one group (N=19) received feedback as text (TXT), a second group (N=15) received feedback by an animated agent (ECA). A third control group (N=9) did not receive feedback message on the smart phone. They could only get feedback via the web portal. Overview of activity is shown graphically in both conditions. Interviews and questionnaires were used at the start, halfway and at the end of the six week period. After a calibration week to measure their regular daily activity level users could set their target activity level themselves. This level is presented as a reference for the actual daily activity.

Results of a six weeks user evaluation with the physical activity coaching system show that Physical Activity Level (PAL) values do not differ between the ECA and TXT condition. Thus feedback by means of an ECA has no added value over feedback by means of a text message if we look at the target objective. The control group that did not receive feedback and no reminders to upload their sensor data performed worse compared to both ECA and TXT group. In particular, in the control group the mean of the PAL values dropped from week 4 onwards. We used a Mann-Whitney U test to compare the results between the different groups. At the end of week 6 the PAL level of the ECA group wa significantly less than the mean for the TXT group ($(Mdn = 1,61), U = 36,00, p = 0,014, r = -0,460$). The number of uploads of PAL data in the control group was significantly less than in the TXT group during all six weeks ($(Mdn = 3,00), U = 51,00, p = 0,045, r = 0,378$).

Interviews and questionnaires reveal that on smartphones users prefer glanceable presentation of feedback messages. Reading the short text message is faster than listening to the spoken message. Smart phones are for quick access and glanceable presentation of feedback fits the message and the use context. In line with the conclusions of Lisetti et al. [28], we believe that the opportunities offered by the technology of animated conversational characters are exploited fully in multi-modal spoken personalised emphatic dialogs with the user. The user evaluations reported by Lisetti et al. had a similar objective as ours but the research methods differ in a number of ways. The most important is that Lisetti uses a lab test; therefore, we had a real-life evaluation. A second important difference is that our ECA platform is based on the BML framework and runs on mobile platforms. This offers new opportunities for coaching systems in clinical applications.

A cross media or multi-device coaching system can support the execution of an intervention program in which a team of human and virtual coaches work towards a negotiated goal, or to sustain a certain lifestyle. Such a blended format combining virtual coaching with real-world coaching is a novelty in HCI design.

IV. User Evaluations: Persuasive Design Factors for eHealth and Social Media Apps

Sexual health is a specific sensitive subject in many cultures and there is little research on the effects of prevention-focused interventions in this domain. The exploratory user study aimed at identifying the design features interventions have to possess to facilitate qualitatively well-designed and tailored eHealth interventions in the future and to evaluate currently available ones. We investigated which design factors are important using

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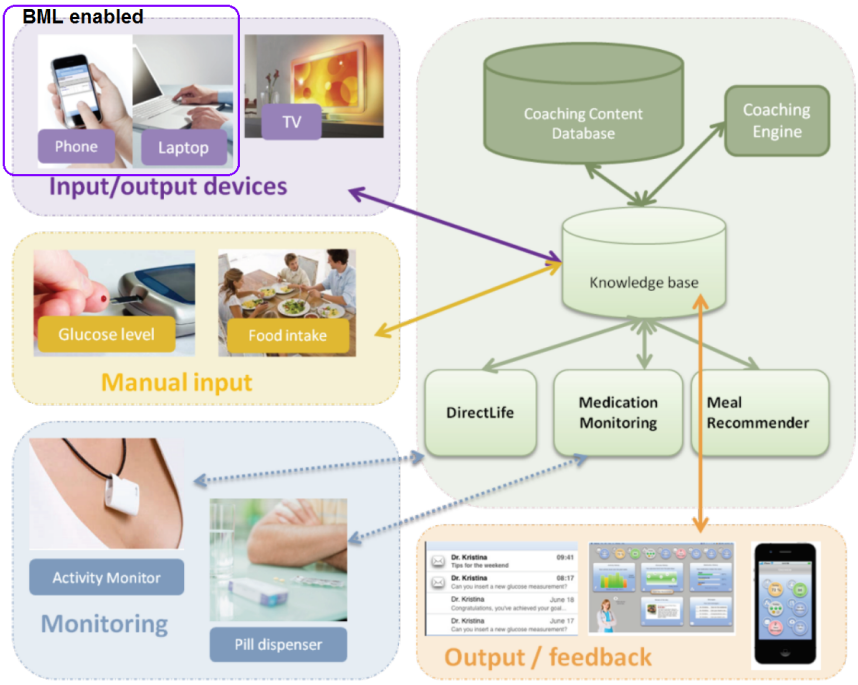

Figure 1: Overview of the multi-sensor multi-device digital coaching system developed in the Smarcos project [25].

focus group discussions with high-risk adolescents. The user study focused on social media, serious games, mobile applications and the use of personal virtual coaching for lifestyle support. Primary research question was which persuasive design factors influence the use and adoption of various eHealth interventions in public sexual health services.

In total, 37 young adults with low socio-economical and various ethnical backgrounds (51, 4% male and 48,6% female; age 12 - 24 years, M=17,4 SD=3,1) participated in four focus group discussions. Participants are considered as having ethnic origin in case if at least one parent comes from abroad. Participants explored and gave feedback on a number of existing and new social media applications and modern media applications in a focus group setting. All sessions were audio recorded with participants permission.

Participants were also asked to express their opinion about the three new concepts for new media applications integrated in modern social media, namely, (i) a serious game embedded in the existing social network, e.g., Facebook, (ii) a mobile application functionality embedded in Facebook, and (iii) a personal virtual coach embedded in either a social network, a website or a mobile application. Each concept represented certain persuasive factors which were discussed using clear visual examples without naming the exact factor.

In the last part, adolescents shared their own ideas and tips about promoting public sexual health services and healthy lifestyle via eHealth applications and social media. The script, the power point slides and the duration of various parts of the focus group session were first tested during a pilot session and adjusted based on the outcome. An assistant took notes and answered questions about the group assignments.

During the data analysis, audio files were fully transcribed, analyzed, coded and categorized. The social support elements have been coded according to the Persuasive System Design model [29]. An analysis of the influence of persuasive factors on the response of adolescents towards various types of presented media was done.

A. *Result of the Focus Group Study*

The results of the focus group study showed that adolescents have positive attitude towards the use of a personal virtual coach for health promotion, as long as they perceive there is a real human behind the virtual character. Several important design factors were identified during the data analysis. Anonymity was found as the most important factor, which has important implications for the use of social networks for sexual well-being enhancement. Social media networks lack privacy and therefore eHealth applications, for example on Facebook, are not a recommended media for enhancing sexual well-being of high-risk adolescents. Instead, social networks can be used to increase the familiarity of the target group with the existing interventions. The next factor, level of interactivity was identified as indispensable. Serious games and mobile applications are expected to have a high level of interactivity to better engage users and thus increase uptake of lifestyle interventions. The type of platform the eHealth technology is realized on was another essential factor. Personal mobile devices, and smart phones in particular, were most preferred due the high level of privacy and familiar user experience. In addition to the factors mentioned above, the reliability of the information source was clearly an important issue across all media types. Participants stated the importance of the clear visibility of the information source, as well as the logo or the name of the health organization behind the intervention. Another factor, namely, support for visual aids, was also identified

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across all types of applications. Specific to adolescents with low soci-economical background, lifestyle interventions have to be more visually aided. The language use in the content has to be simple, low threshold and preferably in several languages to reach various ethnic groups. Applying these factors in the design of eHealth technologies should increase their uptake and usefulness for enhancing sexual well-being of high-risk adolescents and contribute to healthier lifestyle.

V. Lessons Learned: Personal Coaching and Lifestyle Support

What have we learned from studies about the effects of a virtual coach in lifestyle coaching systems? In general, user studies showed positive attitude towards the use of a virtual coach for lifestyle change support. Users prefer to be in control of how, when and on what device they want to receive personal feedback from a virtual coach. In addition, we learned that users want to monitor their history and progress: what they have done and what they should do next. They expect a connection between the goal-setting features for behavioral change and the personal coach to support them.

Motivation is an important factor when it comes to the willingness to use a particular lifestyle coaching system. It makes a difference if an eHealth intervention is supported by a real human healthcare professional. Effective coaching and tailored feedback in terms of its timing, content and interaction design are crucial elements in affecting behavioral change. The next generation of the lifestyle coaching systems will be able to predict the optimal timing for providing feedback by analyzing previously given feedback messages. A personal target has to be challenging and reachable, step by step, within a set period of time.

Next lesson is the need to provide personalized (tailored) feedback: show progress towards target, adjust target, motivate, suggest actions, provide real time information. Facilitating navigation through information that user needs is also found important, for example by offering a user to search information by alternative interaction modalities such as speech input. However, the coach should not talk to the user when the head phone is unplugged. Therefore, a context-sensitive smart sensors technology is needed to enable this feature.

Online coaching also needs to be better integrated with offline feedback to stimulate the participation and commitment of the user to a lifestyle intervention [30]. Combining real-time usage behavior data with personalized virtual coaching and timely persuasive feedback can contribute to higher engagement and better uptake of lifestyle change support system by patients as well as healthcare professionals.

VI. Conclusion and Future Work

Applying user-centered design techniques can significantly improve the appeal of the user interface and thus the engagement with personal lifestyle coaching system [31]. Next to the ease-of-use, visual appeal and clear presentation, the user experience has to be enjoyable and rewarding. Active engagement of the user in interaction with lifestyle intervention is crucial to ensure prolonged use of an intervention.

There is a need for guidelines and standardization for eHealth technology in general [10], as well as for the lifestyle interventions, in particular. In addition, the multi-device architecture is necessary to enable easy exchange of monitoring data between web-based and private mobile parts of lifestyle support systems. This paper makes two contributions: (1) new insights into the existing lifestyle interventions with virtual coaching, their limitations and recommendations for improvements (lack of unanimity in interface and interaction, etc.) and (2) integrated approach, by considering a multi-device eHealth system with motivational design features (such as timely feedback) which increases the involvement of patients as well as healthcare professionals.

To conclude, lifestyle behavior support systems need to be be evaluated throughout all stages of the eHealth technology development cycle. Furthermore, it is also essential to evaluate the effects of eHealth interventions that have already been disseminated, using multidisciplinary approach and by independent evaluators.

A. Future Challenges in Evaluating eHealth Systems

One of the main future challenges in eHealth technology [10] is developing a mixed methods approach and standards for evaluating the effects of eHealth from a user perspective [5] [8]. Validated instruments for user evaluations are needed to measure the effects of personalized eHealth interventions, such as changes in lifestyle or other behavior change [32]. The field of eHealth technology and telemedicine can benefit from adopting design and evaluation methods from the field of HCI. HCI evaluation methods are well suited for the short-term user evaluation to measure the effects of intervention before the long-term implementation. Naturally, HCI evaluation methods need to be adjusted to the specific goal of the eHealth technology and multi-device lifestyle support systems in particular [31]. In return, HCI field can benefit from the active logging methods and eHealth techniques for analyzing usage behavior patterns for better tailoring of personalized feedback [9] [10] [33].

VII. Acknowledgments

We thank all participants of the focus groups and other user studies, Municipal Health Services and social workers. Special thanks are due to Irina Lehmann and Cristel Boom for assistance in recruitment and data analysis. Part of the work presented is funded by the EU, within the framework of the ARTEMIS JU SP8 SMARCOS project 100249. Focus group study is a part of Sense eHealth project funded by the Ministry of Health, Welfare and Sport (VWS) and is carried out in collaboration with the Dutch National Institute for Public Health and Environment (RIVM).

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Critical Success Factors for Inter-Organizational Process Collaboration in eHealth

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Abstract – **In most Western countries, there is substantial growth in inter-organizational cooperation in design and delivery of health services based on Internet technology. However, there is a gap in the literature describing these efforts, and future research as well as practice can benefit from more elaborate theoretical models to understand this phenomenon. In order to close this gap, this study reviews the literature on Business Process Management in an inter-organizational context with a special focus on factors that can explain the success of process development in inter-organizational contexts. The review identifies several critical success factors that may be important as a starting point for future research in eHealth.**

Keywords – Inter-Organizational Collaboration. Business Process Management. eHealth. Information Systems Research. eHealth Literature Review.

I. INTRODUCTION

Integrated processes using eHealth technology in inter-organizational collaborations are needed to accommodate future increasing demands and provide better utilization of scarce specialized-care resources and preventive medicine and care. Such collaboration is not without challenges.

For example, in Norway a new legislation has been passed to ensure close collaboration between hospitals and municipalities, with a strong incentive for more inter-municipal and public-private collaboration (the Norwegian Collaboration reform 'Samhandlingsreformen', passed as law no. 30, June 24, 2011).

Such calls for action often entail a need for process collaboration and integration at an inter-organizational level. What factors determine success or failure of such collaborations?

The purpose of this paper is to study whether literature on Collaborative Business Process Management (CBPM) in an inter-organizational context may inform researchers and practitioners on existing gaps in our knowledge of the sociotechnical factors critically impacting inter-organizational CBPM success, with consequences for eHealth process integration.

We looked at Business Process Management (BPM) as a management strategy [11], supported by more or less integrated tools, ranging from Business Process Modelling Notation as an illustration of 'AS-IS' and 'TO-BE' scenarios, to BPM systems with full workflow integration using service-oriented architecture. BPM has evolved as a synthesis of business process reengineering involving an all-or-nothing redesign of business processes, and total quality management [13] with emphasis on continuous improvement, customer orientation, employee involvement, and other benefits [7, 17]. The BPM subfield of CBPM is defined here as coordinated initiatives that involve actors from inside or outside of an organization, as opposed to non-collaborative BPM, where individuals conduct non-coordinated efforts to alter business processes [14].

Despite growing interest in the subject, there is a gap in the literature as to the importance of context for successful CBPM (Niehaves et al. 2012; ref. Appendix; J15), including inter-organizational contexts where BPM is coordinated between two or more corporations as separate legal entities. EHealth can be defined as the application of the Internet and other related technologies to improve the access, efficiency, effectiveness, and quality of clinical and business processes utilized by healthcare organizations, practitioners, patients, and consumers [9]. This definition is not exhaustive, as eHealth also entails IT-supported measures to promote good health in the general population.

Understanding and succeeding with CBPM in inter-organizational contexts, such as the health sector, represents an increasing relational challenge for many organizations and is thus particularly difficult [15]. Issues may arise due to politics [6], culture [19], or factors related to 'people' [8] and the 'soft side' of organizations [12], which are even more elusive or blurry concepts in an inter-organizational context.

The paper is organized as follows: In the next section, we describe the methods chosen for the literature review in addressing our research questions. Then, we present the results for each research question before we end with a discussion and conclusion regarding the status of the research on CBPM and implications for further research in eHealth.

II. METHOD

First, we looked for existing literature reviews on BPM research; specifically, we looked for overviews of critical success factors for CBPM. We found literature reviews summing up *intra-organizational* factors, collaboration using external consulting resources, culture factors, and general feasibility studies. We did not find any literature

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reviews summing up *inter-organizational* CBPM critical success factors. We addressed this gap by performing our own review of the information system (IS) literature.

This research addressed the following questions:

RQ1: Is successful inter-organizational CBPM perceived differently in eHealth than in current research? Here we want to know how current research has assessed success in terms of the value that is generated from CBPM.

RQ2: Is the success rate of inter-organizational CBPM reported differently in eHealth than in current research?

RQ3: Are the factors that influence successful inter-organizational CBPM in general also identified in the eHealth context?

We adopted the guidelines of a systematic literature review suggested by Webster and Watson [20], von Brocke et al. [18], and Okoli and Schabram [16]. In screening and collecting data from the articles, we adopted the guidelines suggested by Kitchenham et al. [10].

The process of identifying the literature was organized in three steps. The first step involved ten database searches in several databases (Scopus, IEEE, Emerald, ISI Web of knowledge, and others) using the search words 'collaborative business process management', 'BPM', and 'inter-organizational'. We used different truncations of these terms and in different combinations: for example, 'business process', 'management', 'collabo*' OR 'coop*', or 'inter org'. We also did special searches on IS sources with a special focus on BPM, including journals like *Business Process Management Journal* and *Journal of Enterprise Information Management*. We also did a special search for 'BPM' in the proceedings of the Hawaii International Conference on System Sciences (HICSS).

We only included articles in English and that were published after 2004. Our last search was performed on 30 June 2013. This step returned 5.361 titles. However, a screening of the found articles showed that the majority of the articles were irrelevant to our research questions. We excluded articles that did not describe inter-organizational process collaboration or success perspectives or factors, e.g., articles focusing solely on technical feasibility. This screening of articles thus resulted in 47 relevant articles. This led to the third and final step in our search process. We combined forward and backward searches for articles either cited by or citing the previously identified articles, as recommended by Webster and Watson [20]. In this last step, we also included articles from before 2005. This step led us to three additional articles, for a total of 50 (see Appendix). Eleven of these 50 articles reported studies from an eHealth context (Appendix; J1, J3, J5, J7, J11, J12, J15, J28, C8, C9, and C16).

Our search criteria may have omitted articles that focused on inter-organizational CBPM but used other terms. In screening the articles, we may also have omitted articles that should have been included.

III. RESULTS

In this section, we present the findings from our review of the literature according to the three research questions outlined above.

A. How is success assessed in CBPM research?

CBPM is often believed to add substantial value to organizations [15]. Still, the concept of value or successful CBPM is multi-faceted and often implicit in most studies. As a result, we wanted to identify the perspectives used to describe CBPM success in the identified literature. Table 1 shows that CBPM success involves many dimensions, from efficiency of project teams and processes, to effectiveness in goal achievement and quality of work practices involving production of design, products, and services. Success is also understood in some articles as the satisfaction of stakeholders involved in the collaborative processes. For example, in a healthcare context, doctors, patients, and their relatives are examples of important stakeholders in interpreting success.

TABLE 1. PERSPECTIVES ON SUCCESS MEASURES
(with no. of reports)

Perspectives on success	eHealth	other
Efficiency		
Team performance (knowledge and information sharing, service quality)	1	4
Process performance (time, costs, product and process quality)	4	7
Value creation	1	
Satisfaction		
Stakeholder satisfaction (process owner, client, relatives)	1	2
Job effectiveness		1
Information system quality		2
Interoperability, information handoff quality	3	
Achieving legitimacy through standardization		1
Effectiveness		
Goal achievement	1	1
Improved work practices		1
Improved user interface		1
Quality of design and service	1	6
IT innovation		1
Competitiveness		
Market share, profitability, growth, return on investment		3
Innovativeness	1	1
Cost leadership		1
Other perspectives		
Active user participation		1
Multi-party coordination, relationship management capability	1	2
Customer responsiveness		1
Products and services innovation (Complementarity, lock-in)		4
(Organizational) political benefits		1

Perspectives used in eHealth-focused articles are marked with italics.

The perspectives seem to differ with the sector studied. Eleven articles studied or included healthcare. There seems

to be a gap in the inter-organizational CBPM eHealth literature concerning the use of important performance indicators of satisfaction (job effectiveness, information system quality, achieving legitimacy through standardization), effectiveness (improved work practices, improved user interface, IT innovation), competitiveness (market share, profitability, growth, return on investment, cost leadership), active user participation, customer responsiveness, products and services innovation (complementarity, lock-in), and (organizational) political benefits.

B. *Success rates in the eHealth studies compared to other contexts*

Our review shows that the literature reports a lower rate of success for inter-organizational CBPM in eHealth than in other sectors. Of the 11 articles on eHealth contexts, three articles (27%) described successes, while three articles (27%) described full or partial failures. In five of the 11 eHealth articles (45%) this classification was not applicable.

Three articles combine eHealth and other contexts. A total of 42 articles reported on other contexts. Of these, 18 articles (43%) described successful outcomes. Eleven articles (26%) described full or partial failures, and in 13 articles (31%) this classification was not applicable.

From the studies, we cannot conclude whether eHealth has a lower success rate in inter-organizational CBPM projects, or that this level of success is not reported. This may be an indication of gaps in our knowledge on inter-organizational CBPM in eHealth.

C. *What critical success factors are identified in inter-organizational CBPM research?*

We define critical success factors in the context of CBPM (following Butler and Fitzgerald [3] and Eid et al. [4]) as the areas or functions where things must go right to ensure successful performance of the Collaborative Business Process Management efforts. These areas or functions represent barriers or drivers that need managerial attention to ensure that CBPM achieves the projected benefits. In 49 of the 50 articles we identified critical success factors (CSFs), or what could be inferred as CSFs from the narratives, related to CBPM cases or other studies. We organized the list of identified CSFs by the level of analysis of the studies and by the phase of development they reflect in the collaborative BPM projects. The level of analysis ranges from the inter-organizational or network level to the intra-organizational level. Three phases in the life-cycle of CBPM can be identified, following the same pattern as in the work of Blut et al. [2]: phase one, initiation and development; phase two, implementation and early maturation; and phase three, late maturation and renewal or termination. One final group includes studies of critical success factors that did not fit into this framework of phases.

TABLE 2. OVERVIEW OF CRITICAL SUCCESS FACTORS
(with no. of reports)

Critical success factors (#)	eHealth	Other
Inter-organizational level		
1. *Management*	1	4
2. *Maturity*	1	7
3. Partner knowledge	0	3
4. Scalability	0	2
5. Simplicity	0	4
6. *Governance, inter-org.*	1	1
Intra-organizational level		
7. Benefits	0	8
8. *Co-opetition*	1	4
9. *Democratization*	2	1
10. Diffusion of innovation	0	4
11. Experiences	0	2
12. *Finance*	1	2
13. *Governance, org.*	1	3
14. *Information sharing*	2	4
15. *Involvement*	2	3
16. *IS tool quality*	1	5
17. *Resources*	1	5
18. *Support*	1	3
19. *Transparency*	1	5
20. *Accessibility (users)*	1	0
21. Coherency	0	1
22. Consistency	0	1
23. Continuity	0	2
24. Contract clarity	0	2
25. Culture	0	1
26. *Decision promptness*	1	3
27. *Equality*	1	1
28. *Legitimacy*	1	2
29. *Organizational size*	1	0
30. Relationship portfolio	0	1
31. Relationship quality	0	2
32. Responsibility	0	1
33. *Adaptive standards*	1	0
34. *Stepwise implementation*	1	0
35. Strategy and vision	0	2
36. *Terminology*	1	0

Critical success factors used in eHealth-focused articles are marked with italics.

The CSFs found are synthesized into concepts following Webster and Watson's recommendation [20], and numbered for later reference. We identified 36 different concepts reflecting critical success factors for CBPM. These factors can describe different activities depending on the phases of the collaboration life cycle they represent.

Looking at an inter-organizational unit of analysis, successful management style (CSF #1) changes from highly adaptive in early phases (J17, J21) to less adaptive and more determined closer to implementation (J21), with the exception of one study (C8), which also includes adaptive management style in a later phase. Process maturity (#2) is important throughout the first phases, but emphasis changes over the phases from collaboration maturity to technological maturity, including the capability to use CBPM tools. Partner knowledge (#3) is important for the outcome on a business network level. New joint processes, IT solutions, and inter-organizational standards must be scalable (#4) and simple (#5).

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One study (J27) stresses the importance of governance and measurement systems for the collaborative network (#6). Another study claims that it is important that the owners of the e-business 'hubs' do not profit at the participants' expense (finance sector; J11).

On the individual participating organization level, benefit management (#7) seems important. Participants must have a clear idea of what benefits to expect, how to realize them, and how to measure them. Co-opetition in terms of simultaneous cooperation and competition (#8) must be managed throughout the collaboration lifecycle, or benefits may be lost.

Democratization of decision-making and the development of a common vision (#9) are important in the earliest phases of collaboration. Diffusion of collaboration (#10) offers participating organizations additional market and innovation channels, and helps to overcome resource scarcity.

Joint community learning is also identified as a positive side effect of this diffusion. Some studies (C5, C17) found that prior experience with collaboration and experience with performance during the implementation phase (#11) explained success on an organizational level.

Cost reduction (finance; #12) is important. In the implementation phase the financial status of partners may also explain success or failure (J15). Good governance of projects, contracts, and IT are identified as a CSF (#13). One paper (J4) argues for a service broker function for better governance (in the context of implementing cloud computing services; J4). Information and knowledge sharing across functions (#14) are dominant factors, especially in the early phases of collaboration (J27, J28, C12, C20). One study from the health-care sector explores the importance of information handoff processes for patient safety. User involvement (#15) is a dominant factor in both the development (J17, J28, C3) and implementation phases (J3, J24). Resources (competence, capacity, capabilities; #16) are needed for change management, and training employees in new practices. Support (#18) must be provided for the innovation and collaboration processes. Many studies emphasize the need for transparency (#19) in process design and technological solutions.

User accessibility plays a great role in e-government solutions (#20). The need for coherent public policies is also apparent in e-government standards development (C4; #21). Within supply chains it is suggested that collaborative solutions (using the Internet) should have a consistent strategy and focus on value creation, not just cost reduction (J6; #22). Other special critical success factors found in some studies are continuity (in use of collaborative tools; # 23), contract clarity (#24), and management of cultural differences (#25). Decision promptness is identified by some studies (J17, J27, J28, C17; #26), but seems to contradict other studies (e.g. J21) that emphasize adaptive management and democratization. Equality of participants is found to be a factor in some business networks (J11, J27; #27). Legitimacy of the change process in the eyes of the organization's constituents is found to be of importance, especially in public administration (J12, C15, C17; #28). Organizational size is also identified as a success factor in public sector CBPM projects (J15; #29), with smaller organizations more eager to collaborate with others. Concentrating the portfolio of partner relationships is identified as a success factor in some chemical and mechanical industries (J18; #30). Organizational size and portfolio concentration may arguably be related to the resource concept (#17) as a success factor. Relationship quality (#31) involves external partners in business process outsourcing (J8) and process collaborations in industries (J18). Responsibility (commitment to change process objectives; #32) is identified as a success factor by a panel of BPM experts (J24). Standardization can in some instances be a barrier for performance. Transparency (#19) is important, but premature standardization that conflicts with actual workflows has in one case proven to be detrimental to collaborative performance in healthcare (J7), so an adaptive standardization process is a success factor (#33). A stepwise implementation of new processes can be one way to avoid issues (J1; #35). Developing a common terminology stimulates CBPM in processes characterized by high quality and intensity, such as in healthcare (J5; #36).

We found some CSFs that seem to be of potential significance in eHealth:

Decision promptness (#26): Prompt actions when issues were raised in an implementation project, taking feedback seriously, and solving issues before further rollout of new solutions were significant factors in a physician order entry system and in patient health record systems (J28).

Equality of participants (#27): Power balances in partnerships are necessary to attract participants, as reported by case studies in the Global Healthcare Exchange (GHX) (J11).

Legitimacy (#28): Legitimacy of initiatives (in the eyes of stakeholders) is necessary for successful e-government initiatives and in the adoption of Service Oriented Architecture (SOA) and information infrastructure for governmental services (C15, C17), and is a prerequisite for implementing welfare technologies for assisted living at home for elderly and chronically ill patients [42; p. 90].

Organizational size (#29): Smaller organizations, such as smaller municipalities, may have restricted opportunities for sourcing new services internally and are more dependent on external sourcing and collaboration (J15). In Norway, as in other countries with a geographically scattered population, ideal municipality size is debated. The assumption is that bigger municipalities may provide better services, but smaller organizational size can make collaboration less complex and easier to manage and may be a positive driving

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force for CBPM. This might result in a higher success rate of CBPM in small municipalities.

Flexible/mature standards (#33) and a stepwise implementation (#34): Kauffman and Tsai (J7) cite a case study in Norwegian hospitals where a premature standardization project (electronic patient record) had negative effects on organizational performance and care practices. The proposed new standards did not fit the information system environment and did not capture the needs of the work processes, resulting in more fragmented patient records. Albani and Dietz (J1), using examples from healthcare, argue for a stepwise implementation, where experiences are gradually taken into consideration when going from local to global coordination. They call this the 'choreography of business processes'.

On the other hand, many inter-organizational non-eHealth CBPM critical success factors are missing in the eHealth context (Table 2; CSF# 3-5, 7, 10-11, 21-25, 30-32, and 35). We cannot conclude whether awareness of some factors is irrelevant to eHealth or simply not reported. This gap indicates that further research is needed.

IV. DISCUSSION

In general, studies from the public sector are more often concerned with satisfaction of involved stakeholders and quality of services and less concerned with efficiency and competitiveness. As McNulty (J12) reports, an emerging process perspective on eHealth, with its emphasis on value creation, will challenge deeply rooted functional perspectives that emphasize control.

Most studies have adopted a perspective where collaboration in the inter-organizational context of BPM is seen as largely free from competition and conflict. Five notable exceptions study competition as a barrier to collaboration (J2, J9, J12, C2, C17). Organizations also compete in the public sector; for example, municipalities and institutions compete for positions, location of shared functions, and funding resources. Competition as a barrier may extend from an individual level to become an inter-organizational challenge. These barriers can become a major problem for society.

In the cases described, some critical success factors seem to be particularly context-dependent (CSF # 6, and 20-36 in table 2). Further studies should investigate their generalizability. More research is needed to understand critical success factors across different sectors and phases of collaboration, and to create a more holistic understanding of inter-organizational CBPM.

As we have shown, there are gaps and inconsistencies in success factors within eHealth. For example, intra-organizational governance is also important in the eHealth sector, but there is limited information on what performance measures or perspectives of success such governance initiatives should focus on. This corresponds also with some of the lacking critical success factors, for instance the benefits concepts and relates to the success rate of eHealth research in general. These gaps suggest a need further research. We believe that researchers of CBPM in eHealth can benefit from critical success factors identified in other contexts and can use them as a basis for conceptualization and empirical testing in an eHealth context.

The eHealth sector in particular poses special challenges for both decision-makers and lawmakers. A coherent roadmap for successful implementation of complex eHealth inter-organizational CBPM initiatives will require attention to multiple factors; thus far, we only have scattered case studies on which to build our understanding of these factors.

Our review identified a wide variety of theoretical approaches used to date. A unified theoretical framework could stimulate further development in the field. An interesting starting point for this integration could be studies of value creation in e-business models (Amit and Zott [1]) that are inter-organizational and process-focused [5], covering many challenges similar to those in inter-organizational CBPM.

V. CONCLUSION

There are gaps in our understanding of inter-organizational process collaboration in eHealth. Many critical success factors and perspectives reported in other contexts are missing in the eHealth context but could prove important in the field of eHealth. The reported success rate of CBPM in an eHealth context seems to be lower than in other contexts, but the sample size of eHealth-related studies is too small to allow for any decisive conclusions. Some critical success factors must be given special consideration in an eHealth context. Are we missing pieces of the puzzle for successful inter-organizational CBPM implementation in eHealth?

Further research is needed on the content, relevance, and impact of sociotechnical factors like *co-opetition* management (ref. Appendix; J2, J9, and J12), as the successful balance between simultaneous *cooperation*, or collaboration, to achieve coherent patient treatment, and *competition* for positions, resources, and funding. Further research is also needed on the relative weight of the different factors over different phases of collaboration.

This research will inform further eHealth research and successful eHealth initiative implementation, and will be of use to lawmakers and regulators.

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VII. APPENDIX

1) Journal articles reviewed

ID	Reference
J1	Albani, A. and Dietz, J. L. (2009), 'Current trends in modeling inter-organizational cooperation', *Journal of Enterprise Information Management*, 22(3), pp. 275-297.
J2	Baruch, Y. and Lin, C. P. (2012), 'All for one, one for all: coopetition and virtual team performance', *Technological Forecasting and Social Change,* 79(6), pp. 1155-1168.
J3	Bochicchio, M., Bruno, A. and Longo, A. (2011), 'Supporting Continuous Improvement in Care Management with BPM', *Software Engineering,* 1(2), pp. 32-38.
J4	Demirkan, H. and Goul, M. (2013), 'Taking value-networks to the cloud services: security services, semantics and service level agreements', *Information Systems and e-Business Management*, 11(1), pp. 51-91.
J5	Gogan, J. L., Baxter, R., Boss, S. R. and Chircu, A. (2013), 'Handoff Processes, Information Quality and Patient Safety: A Trans-Disciplinary Literature Review', *Business Process Management Journal*, 19(1), pp. 70-94.
J6	Jonsson, S. and Gunnarsson, C. (2005), 'Internet technology to achieve supply chain performance', *Business Process Management Journal*, 11(4), pp. 403-417.
J7	Kauffman, R. J. and Tsai, J. Y. (2010), 'With or without you: The countervailing forces and effects of process standardization', *Electronic Commerce Research and Applications*, 9(4), pp. 305-322.
J8	Lacity, M. C., Solomon, S., Yan, A. and Willcocks, L. P. (2011), 'Business process outsourcing studies: a critical review and research directions', Journal of information technology, 26(4), pp. 221-258.
J9	Lin, C. P., Wang, Y. J., Tsai, Y. H. and Hsu, Y. F. (2010), 'Perceived job effectiveness in coopetition: a survey of virtual teams within business organizations', *Computers in Human Behaviour*, 26(6), pp. 1598-1606.
J10	Magdaleno, A.M., Cappelli, C., Baiao, F.A., Santoro, F.M. and Araujo, R. (2008), 'Towards collaboration maturity in business processes: an exploratory study in oil production processes', *Information Systems Management*, 25(4), pp. 302-318
J11	Markus, M. L. and Bui, Q. N. (2012), 'Going concerns: the governance of inter-organizational coordination hubs', *Journal of Management Information Systems*, 28(4), pp. 163-198.
J12	McNulty, T. (2003), 'Redesigning public services: challenges of practice for policy', *British Journal of Management*, 14(s1), pp. S31-S45.
J13	Münstermann, B., Eckhardt, A. and Weitzel, T. (2010), 'The performance impact of business process standardization: An empirical evaluation of the recruitment process', *Business Process Management Journal*, 16(1), pp. 29-56.
J14	Niehaves, B. and Plattfaut, R. (2011), 'Collaborative business process management: status quo and quo vadis', *Business Process Management Journal*, 17(3), pp. 384-402.
J15	Niehaves, B., Plattfaut, R. and Becker, J. (2012), 'Business process governance: a comparative study of Germany and Japan', *Business Process Management Journal*, 18(2), pp. 347-371.
J16	Pramatari, K., Evgeniou, T. T. and Doukidis, G. (2008), 'Implementation of collaborative e-supply-chain initiatives: an initial challenging and final success case from grocery retailing', *Journal of Information Technology*, 24(3), pp. 269-281.
J17	Puschmann, T. and Alt, R. (2005), 'Developing an integration architecture for process portals', *European Journal of Information Systems*, 14(2), pp. 121-134.
J18	Rai, A. and Tang, X. (2010), 'Leveraging IT capabilities and competitive process capabilities for the management of interorganizational relationship portfolios', *Information Systems Research*, 21(3), pp. 516-542.
J19	Rajaguru, R. and Matanda, M. J. (2009), 'Influence of inter-organisational integration on business performance: the mediating role of organisational-level supply chain functions', *Journal of Enterprise Information Management,* 22(4), pp. 456-467.
J20	Reijers, H. A. (2006), 'Implementing BPM systems: the role of process orientation', *Business Process Management Journal*, 12(4), pp. 389-409.
J21	Ritala, P., Hurmelinna-Laukkanen, P. and Nätti, S. (2012), 'Coordination in innovation-generating business networks–the case of Finnish Mobile TV development', *Journal of Business & Industrial Marketing*, 27(4), pp. 324-334.
J22	Rohloff, M. (2011), 'Advances in business process management implementation based on a maturity assessment and best practice exchange', *Information Systems and E-Business Management*, 9(3), pp. 383-403.
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J29 Venkatesh, V. and Bala, H. (2012), 'Adoption and impacts of inter-organizational business process standards: Role of partnering synergy', *Information Systems Research*, 23(4), pp. 1131-1157.

J30 vom Brocke, J. and Sinnl, T. (2011), 'Culture in business process management: a literature review', *Business Process Management Journal*, 17(2), 357-378.

B. Conference articles reviewed

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C2 Eikebrokk, T. R. and Olsen, D. H. (2005, January), 'Co-opetition and e-business success in SMEs: an empirical investigation of European SMEs', *In 2005 proceedings of the 38th Annual Hawaii International Conference on System Sciences (HICSS)*, IEEE, pp. 162a-162a.

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Does Telecare have an Economic Effect when Used by Patients with Chronic Diseases in the Long Run?

Based on Nine-Year Data from Nishi-Aizu Town, Fukushima Prefecture, Japan

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***Abstract*— This study aims to demonstrate that telecare (e-Health) is one essential measure for coping with increases in medical expenditure related to chronic diseases such as heart failure, high blood pressure, diabetics, and stroke. To do so, the long-term effects of telecare use by residents of Nishi-aizu Town, Fukushima Prefecture, Japan, between 2002 and 2010 is examined by comparing medical expenditure and days of treatment between telecare users (treatment group) and non-users (control group) based on receipt data obtained from the National Health Insurance. Our previous studies used receipt data obtained for the years 2002 to 2006. This study expands the period of analysis for four more years with respect to respondents who were included in previous analyses. 90 users and 118 non-users were included in both analyses. Using rigorous statistical methods, including system Generalized Method of Moments (GMM), which deals with the endogeneity problem, this paper demonstrates that telecare users require fewer days of treatment and smaller medical expenditures than non-users with respect to chronic diseases, even in the long run. To date, there have been no studies examining the long-term economic effects of telemedicine use, and thus the current study presents a new facet of research in this field. In particular, the economic foundation for the sustainability of the telecare (e-Health) project will be supported by this study.**

Keywords- telecare; medical expenditure; days of treatment; System GMM; chronic diseases.

I. INTRODUCTION

Increasing medical costs and shortages of medical doctors in rural areas are issues that urgently need to be addressed in healthcare around the world. Medical expenditure in Japan has been steadily increasing, and in FY2012 amounted to JPY35.1 trillion (US$4,387 billion) with more than half (51.7%) of that being spent on the care of patients over the age of 65. In 2012, 24.2% of the Japanese population was over the age of 65, and this is expected to increase in the near future. Furthermore, the number of outpatient days in Japan is the largest among the OECD member countries at 13.4 days per person per year, compared with 4.0 (US), 5.9 (UK), 7.8 (Germany), and 6.9 (France) days per person per year (OECD Health Data). It is imperative to reduce the number of treatment days as well as overall medical expenditure in Japan. To cope with the serious healthcare situation in Japan, local governments have begun to implement telecare, or e-Health, which allows the local government to remotely monitor the health of elderly residents at home by transmitting health-related data, such as blood pressure, blood oxygen level, and ECG, to medical institutions via telecommunications networks. Telecare is thus expected to improve users' health, as our previous studies[1][2][3][4] demonstrated.

The present study selected Nishi-aizu Town as the project site. This town, located in Fukushima Prefecture, Japan, has nearly 20 years experience with telecare. The objective of the paper is to demonstrate that telecare use reduces not only medical expenditures but also days of treatment of patients with chronic diseases such as stroke, hypertension, heart failure, and diabetes, even over the long-term period of nine years. In addition, a rigorous statistical method, system Generalized Method of Moments (GMM), is used to statistically assess the causal relationship through which telecare use actually reduces medical expenditure and days of treatment. This relationship is not "seemingly correlated"[3][5][6]. In order to carry this out, field research was conducted in March 2012 to obtain two basic data for the statistical analysis; receipt data for 272 telecare users (treatment group) and 247 non-users (control group) for the period 2007 to 2010, and their responses to a questionnaire. This data included individuals who were included in our previous studies in the period 2002 to 2006, and thus data for 90 telecare users and 118 non-users for the whole period 2002 to 2010 were used in this study.

Another objective of this paper is to focus on medical expenditure and days of treatment of patients with particular chronic diseases such as stroke, hypertension, heart failure, and diabetes, since the increase in the number of chronic diseases is one of the major reasons for medical expenditure rises worldwide. Although the previous paper[7] compared these two outcomes for general users and nonusers for five- and nine-year data, this paper examines whether the same results hold particularly for patients with chronic diseases. The rationale for this research question is that the increase in medical expenditures is a common global issue and it is generally understood that the increase in chronic diseases is the major cause. Moreover, it is well known that chronic diseases can be prevented by lifestyle changes, for example. In this context, this study can provide one solution to these issues.

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Another objective of this study is to compare the results from the same telecare project in Nishi-aizu obtained by our previous studies[1][2][3][4]. These studies cover the data for 199 telecare users (treatment) and 209 non-users (control) in the period 2002-2006. The results of this five-year period are summarized as follows: (i) telecare users had lower medical expenditures for chronic diseases than non-users; (ii) the longer the subjects used telecare, the lower the medical expenditures became; (iii) the longer the subjects used telecare, the larger the elasticity of the reduction of medical expenditures became; that is, the more years users utilized telecare, the greater the decrease in medical became for each additional year of use compared with those whose years of use were fewer; and (iv) the effect of the reduction of medical expenditures due to telecare is higher, especially for telecare users with chronic diseases.

The same hypotheses are applicable to treatment days. This paper thus compares the results for the five-year and nine-year research. This paper consists of the following sections. Section II describes the usage of the telecare system in Nishi-aizu, Section III outlines the materials and methods of the paper, Section IV indicates the results of the estimations, and in Section V we state our conclusions.

II. TELECARE USAGE IN NISHI-AIZU

Here we describe the background and history of the telecare system in Nishi-aizu.

A. Healthcare in Nishi-aizu

Nishi-aizu is located in the northwest corner of Fukushima Prefecture, Japan, and is an important point of transit to and from Niigata Prefecture and the nearby major city of Aizu-wakamatsu. The town is surrounded by mountains, which cover 86% of the prefecture, and the town center is located in a geographical basin. There are approximately 10,000 residents in 3,000 households, and in 2001, 35.9% of the population was over the age of 65. The town's main industry is agriculture, and rice is the main product. The climate is characterized by very high temperatures in summer and very low temperatures with heavy snow in winter. The severe winter conditions deprive the elderly residents of opportunities for sufficient physical exercise. Furthermore, due to a traditional diet of salty and protein-poor foods, the town's death rate was 1.7 times higher than the national average between 1983 and 1987, with relatively high rates of stomach cancer. The number of bedridden elderly people suffering from osteoporosis or arthritis is also higher than the national average[8].

B. Introduction of the telecare system in Nishi-aizu

The town introduced telecare in 1994 to reduce the incidence of chronic diseases such as cerebral infarction and stroke. Three hundred peripheral devices, called "Urara," manufactured by Nasa Corporation, were provided to residents with chronic diseases. The Urara device is connected to a host computer via a public switched telephone network. Health-related data such as the user's blood pressure, pulse rate, ECG, blood oxygen level, weight, and body temperature are transmitted to a server operated by the town. In 1996 and 1997, an additional 50 terminals were purchased with subsidies from the Japanese Ministry of Agriculture and Fisheries. In 2002/2003, an additional 187 terminals were purchased with the town budget. The town thus currently owns 587 terminals. These terminals use the CATV network for transmitting data. All the costs of operating the system are paid for by the local government. The Urara devices are distributed to the following three groups of patients: (i) elderly residents with diseases, (ii) elderly residents who have been referred by a doctor, (iii) other residents who are living alone or referred by a doctor[9].

C. Operation of the telecare system in Nishi-aizu

The Nishi-aizu Department of Health and Welfare oversees the administration of the telecare system. Six public health nurses check the health data transmitted by the Urara devices and use that data as part of their consultations with users. If these nurses observe unusual data, they ask a medical doctor from one of the clinics to visit the user in question. The health data for each user are summarized in a monthly report, which is then sent to the physician in charge. After the physician and a public health nurse add their comments, the report is sent to the user. When the user visits a doctor, they are asked to bring the report with them (see [9] for more details).

The telecare system is operated as part of the town's "Project for Promoting Total Care," and the underlying principle is close collaboration between the health, medical, and welfare activities in the town. Regional Care Meetings are an important example of this collaboration. More than 20 people attend each meeting, which consists of doctors, nurses, public health nurses, town office staff, care-takers of the elderly, and lifestyle advisers. At these meetings, medical care for individual telecare users, such as necessary medical examinations, specific health advice, and general healthcare issues, are discussed in detail, the telecare health data playing a central role. To improve the residents' motivation for using the telecare system, the town office organizes telecare users' meetings five times a year. At the meetings, users can exchange their experiences and views of using the system. In fact, our in-depth interviews conducted with public nurses working in Nishi-aizu revealed that the number of patients with chronic diseases visiting doctors decreased with increasing telecare use.

The introduction of the telecare system should not be considered the sole factor promoting better regional healthcare; rather, it should be seen as the framework that assists all the departments and personnel involved to deliver more effective health care.

III. MATERIALS AND METHODS

Here we outline the materials and methods used in this paper.

A. Sample selection

Here two kinds of data for analysis, namely receipt data and responses of questionnaire are explained. In our previous study, the receipt data for 199 users and 209 non-users collected between 2002 and 2006 was obtained from the National Health Insurance. The receipts for each month are kept at the Nishi-aizu town office, and include a range of information. In the current study, the following data were used: (i) name of patient, (ii) birth date, (iii) regular outpatient treatment or hospitalized

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patient treatment, (iv) name(s) of major disease(s), (v) date of initial treatment, (vi) number of days of treatment was needed, and (vii) the medical treatment "points" (one point is equivalent to JPY10).

Next the receipt data for the years 2007 to 2010 was collected. To ensure that the patients included in the previous studies were also included in the current study, we first checked whether they responded to the questionnaire survey (whether the person had deceased or not, etc.); about half of the subjects failed to respond, which resulted in a lack of samples. We therefore selected 565 new subjects from among the telecare users. The questionnaire used in this study was the same as that used in our previous studies. The questionnaire asks for information on characteristics such as sex, age, and the individuals' use of the telecare system, which is data not included in the receipt data. Non-users were selected by stratified sampling from the list of subscribers to the National Health Insurance, which amounted to 1035 non-users. The respondents are summarized in Table I, which shows that 272 users and 247 non-users were selected as valid respondents for this study; 91 users and 118 non-users were included in both the previous study and the current study. We then collected the data mentioned above (regarding the construction of data, see [9] in more detail.).

TABLE I. RESPONDENTS TO MAIL QUESTIONNAIRE

		No. of residents sent questionnaire	No. of valid respondents (No. of valid respondents between 2002 and 2009)
2007 Survey	Users	412	199
	Non-users	450	209
	Total	862	408
2012 Survey	Users	565	272 (91)
	Non-users	1035	247 (118)
	Total	1600	519 (209)

B. Summary of mail survey

The percentages of users and non-users by gender is shown in Table II. The percentage of males (57.1%) is higher than that of females (42.9%).

TABLE II. GENDER

	Users (%)	Non-users (%)	Total (%)
Male	52 (57.1)	72 (61)	124 (59.3)
Female	39 (42.9)	46 (39)	85 (40.7)
Total	91	118	209

Table III shows average ages of samples and since the same persons are compared average age of 2012 sample is five years older than that of 2007.

TABLE III. AVERAGE AGE OF RESPONDENTS

	N	Average age (2007)	Average age (2012)
Users	91	70.67	75.67
Non-users	118	70.76	75.76

The telecare system in Nishi-aizu was implemented to help in the management of chronic diseases such as heart disease, hypertension, diabetes, and stroke. Table IV shows the number of patients with these four diseases that were treated within the study period. Hypertension was the most common of these four diseases, followed by heart disease.

Table V summarizes the number of years of individual telecare use. Users that had used the telecare system for more than 10 years accounted for 25.6% of the total number of users, which is the largest percentage, and this makes examination of the long-term effect of the system possible. The number of respondents who replied that they did not use the telecare system accounted for 30% of the respondents, which is larger than expected. It is possible that they responded that they did not use the system since they became too old, even though they had a telecare device in their homes.

TABLE IV. SELECTED DISEASES TREATED BETWEEN 2002 AND 2010

	Users (%)		Non-users (%)		Total (%)	
	2002–2006	2007–2010	2002–2006	2007–2010	2002–2006	2007–2010
Heart disease	19 (0.21)	19 (0.21)	15 (0.13)	15 (0.13)	34 (0.16)	34 (0.16)
Hypertension	49 (0.54)	51 (0.56)	40 (0.34)	57 (0.48)	89 (0.43)	108 (0.52)
Diabetes	8 (0.09)	11 (0.12)	9 (0.08)	14 (0.12)	17 (0.08)	25 (0.12)
Stroke	5 (0.06)	8 (0.09)	7 (0.06)	9 (0.08)	12 (0.06)	17 (0.08)

TABLE V. YEARS USING TELECARE

	2007 (%)	2012 (%)
Less than 1 year	2 (2.2)	0 (0)
1–3 years	15 (16.5)	8 (8.8)
3–5 years	19 (20.9)	8 (8.8)
5–7 years	21 (23.1)	11 (12.1)
7–10 years	16 (17.6)	13 (14.3)
>10 years	18 (19.8)	23 (25.3)
Do not use	2 (2.2)	27 (29.7)
Not answered	0 (0)	1 (1.1)
Total	91	

TABLE VI. FREQUENCY OF USE

	2007 (%)	2012 (%)
Almost every day	41 (45.1)	27 (29.7)
3–4 times a week	22 (24.2)	15 (16.5)
1–2 times a week	10 (11)	7 (7.7)
1–2 times a month	11 (12.1)	7 (7.7)
Rarely use	6 (6.6)	24 (26.4)
Not answered	1 (1.1)	11 (12.1)
Total	91	

Table VI summarizes frequency of telecare use. More than half of the respondents reported that they used the telecare system at least once a week to communicate with a nurse or to

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alert medical staff of distress or discomfort. This high frequency of use is possibly due to the town office's efforts in holding public meetings to educate users in the use of the system, as already mentioned. One fourth of respondents answered that they rarely use the telecare system, which corresponds with the number of users who answered that they do not use the system (Table V).

D. Method of estimation

The outcome variables of days of treatment and medical expenditure are not stable over the study period, and it is difficult to assess whether there are any differences between users and non-users over the study period. Rigorous statistical analyses are therefore necessary. We thus employed a regression analysis to assess whether telecare use reduces days of treatment and/or medical expenditure. Studies in this field face a number of important methodological issues. First, there is the problem of endogenous explanatory variables. One method of solving this is by using system GMM, which allows treatment of not only endogenous explanatory variables but also of the dynamic relationships among the variables that arise due to the chronic time-lagged effect of chronic diseases on patients. Moreover, system GMM is able to deal with the reverse correlation between outpatient medical expenditure and telecare use. In this context, we attempted to demonstrate causality between telecare use and decreased medical expenditures, or, in other words, to show that the relationship is not seemingly correlated. A number of previous studies have successfully attempted to handle endogeneity problems in telemedicine and telecare evaluation[3][5][6].

IV. RESULTS

Here we set out the results of our estimations.

A. Model for estimation

In the estimation, the dependent variables were (1) days of treatment of outpatients, all diseases, (2) medical expenditure for outpatients, all diseases, (3) days of treatment of outpatients, chronic diseases, and (4) medical expenditure for outpatients, chronic diseases. The explanatory variables were telecare use (if users, 1; otherwise, 0), age, income, and the presence of any of the four main chronic diseases such as heart disease, hypertension, diabetes, and stroke (if treated, 1; otherwise, 0). In addition, other factors were added as instrumental variables, such as dummy variables for sex or year dummies. System GMM estimators developed by Arellano–Bond, Arellano–Bover, and Blundell–Bond are general estimators for coping with data that have "small T, large N" panels. System GMM can be used in models in which the independent variables are not strictly exogenous, namely, those correlated with past and possibly current realizations of the error. System GMM can also be used to treat data with heteroskedasticity. The Arellano–Bond test for AR (2) (second stage autocorrelation), the test of weak instruments, and the Hansen test for over-identifying restrictions were used.

B. Estimation results, all diseases

Tables VII and VIII show the results of the estimation using system GMM. The coefficient of telecare use is negatively significant for days of treatment ($p<0.10$) and medical expenditure ($p<0.05$). These findings imply that telecare contributed to reductions in days of treatment and medical expenditure. However, the Arellano–Bond test for AR (2) for the model of medical expenditures (see Table VIII) showed that there was autocorrelation under the 1% significance level. This means that serial correlation of the error terms cannot be denied, and accordingly, the estimates still have small biases. The test of weak instruments showed that instruments and endogenous variables used are correlated significantly, which indicates exemption from a problem of weak instruments. Furthermore, the Hansen test for over-identifying restrictions showed that the instrumental variables were properly chosen. This means that the model specification was adequate and that the parameters were significant and robust. In addition, age is positively significant for both days of treatment and medical expenditure ($p< 0.01$), which is natural considering that days of treatment and medical expenditure increase with age. Finally, the coefficients of three chronic diseases (heart disease, hypertension, and diabetes) are positively significant for both days of treatment and medical expenditure. According to the estimations, telecare use reduces days of treatment for all diseases by 7.9 days per user per year, and medical expenditures for all diseases by approximately JPY 106,904 per user per year. However, the latter may contain biases due to serial correlation, and therefore the result may not be reliable.

TABLE VII. RESULT OF SYSTEM GMM (1): DAYS OF TREATMENT (OUTPATIENTS, ALL DISEASES)

	Coefficient	SD	*t* value	*p* value	
Telecare use	–7.889	4.081	–1.93	0.053	*
Age	0.125	0.022	5.66	0.000	***
Income	–0.003	0.007	–0.43	0.664	
Heart disease	16.031	8.880	1.81	0.071	*
Hypertension	15.688	1.962	8.00	0.000	***
Diabetes	11.809	5.199	2.27	0.023	**
Stroke	–3.657	8.395	–0.44	0.663	
Number of observations				1820	
Arellano–Bond test for AR (2) (*p* value)				0.109	
Test of weak instruments (*p* value)				< 0.01	
Hansen test for over-identifying restrictions (*p* value)				0.144	

Note: ***, **, and * indicate levels of significance of 1%, 5%, and 10%, respectively.

C. Estimation results, chronic diseases

The same models were applied for patients with chronic diseases. The other variables were the same as in the previous estimations. Tables IX and X summarize the results of these estimations. Both the Arellano–Bond test for autocorrelations, the test of weak instruments, and the Hansen test for over-identifying restrictions were satisfied, since they were not significant ($p =0.692$). Thus, the instrumental variables were selected appropriately. The coefficients for telecare use were negatively significant for both days of treatment ($p<0.05$) and medical expenditure ($p<0.05$). Age was again positively significant for both outcomes ($p<0.01$). In contrast to the previous estimation, only hypertension was positively significant for days of treatment ($p<0.01$) and medical

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expenditure ($p<0.01$). This means that hypertension is a major contributing factor to days of treatment and medical expenditures. The coefficients indicate that telecare use reduces days of treatment for chronic diseases by 4.2 days per user per year, and medical expenditure for chronic diseases by JPY 64,944 per user per year.

TABLE VIII. RESULT OF SYSTEM GMM (2): MEDICAL EXPENDITURE (OUTPATIENTS, ALL DISEASES)

	Coefficient	SD	*t* value	*p* value	
Telecare use	–10690.36	5232.40	–2.04	0.041	**
Age	134.54	30.15	4.46	0.000	***
Income	–5.82	7.61	–0.76	0.444	
Heart disease	31937.81	10053.93	3.18	0.001	***
Hypertension	17968.45	2278.68	7.89	0.000	***
Diabetes	13425.88	6351.97	2.11	0.035	**
Stroke	–20272.70	13779.70	–1.47	0.141	
Number of observations				1820	
Arellano–Bond test for AR (2) (*p* value)				0.005	
Test of weak instruments (*p* value)				< 0.010	
Hansen test for over-identifying restrictions (*p* value)				0.563	

Note: ***, **, and * indicate levels of significance of 1%, 5%, and 10%, respectively.

TABLE IX. RESULT OF SYSTEM GMM (3): DAYS OF TREATMENT (OUTPATIENTS, CHRONIC DISEASES)

	Coefficient	SD	*t* value	*p* value	
Telecare use	–4.223	1.957	–2.16	0.031	**
Age	0.053	0.012	4.50	0.000	***
Income	0.002	0.004	0.47	0.637	
Heart disease	1.761	3.873	0.45	0.649	
Hypertension	9.061	1.111	8.16	0.000	***
Diabetes	3.370	2.471	1.36	0.173	
Stroke	–3.856	4.621	–0.83	0.404	
Number of observations				1820	
Arellano–Bond test for AR (2) (*p* value)				0.415	
Test of weak instruments (*p* value)				< 0.01	
Hansen test for over-identifying restrictions (*p* value)				0.231	

Note: ***, **, and * indicate levels of significance of 1%, 5%, and 10%, respectively.

TABLE X. RESULT OF SYSTEM GMM (4): MEDICAL EXPENDITURE (OUTPATIENTS, CHRONIC DISEASES)

	Coefficient	SD	*t* value	*p* value	
Telecare use	–6494.41	3215.58	–2.02	0.043	**
Age	70.83	19.37	3.66	0.000	***
Income	–3.11	8.25	–0.38	0.707	
Heart disease	6885.39	4903.83	1.40	0.160	
Hypertension	9714.75	1466.91	6.62	0.000	***
Diabetes	5606.42	4452.80	1.26	0.208	
Stroke	–6857.28	6447.90	–1.06	0.288	
Number of observations				1820	
Arellano–Bond test for AR (2) (*p* value)				0.165	
Test of weak instruments (*p* value)				< 0.01	
Hansen test for over-identifying restrictions (*p* value)				0.692	

Note: ***, **, and * indicate levels of significance of 1%, 5%, and 10%, respectively.

D. Comparison with the results of five year data

Table XI summarizes the results from our previous study of the five-year period between 2002 and 2006[1][2][3]. The results obtained in the current study are larger than those reported previously, which means that telecare use produces both long-term and short-term effects. Therefore, the longer patients use telecare, the larger the reductions in days of treatment and medical expenditure.

The analysis of the nine-year period only demonstrated the result (i); telecare users had a lower medical expenditure on chronic diseases than non-users. Regarding the result (ii); the longer the subjects use telecare, the lower medical expenditures become, [10] demonstrated this result by using the difference-in-difference propensity score matching (DID-PSM) method, which enables examination of the time trend effect. In particular, for patients with chronic diseases, medical expenditures over 10 years are reduced by JPY21,194.6 (US$235,5) ($p<0.05$), and treatment days by 1.73 days ($p<0.05$) per year per user. These are smaller than the results obtained in this paper. Other results obtained in the five-year data are unable to show reductions mainly due to the small number of subjects in the 2012 research. In addition, further rigorous statistical inference is required.

TABLE XI. PREVIOUS RESULTS FROM FIVE-YEAR DATA

	OLS[1]	System GMM[2]	PSM[3]
Medical expenditure	JPY 15,302 (US$ 191.28)	-	JPY 25,538–39,936 (US$ 319.23–499.20)
Days of treatment	1.6 days	2.0 days	2.6–4.0 days

Note: [1]Akematsu and Tsuji (2009), [2]Minetaki, Akematsu, and Tsuji (2011), [3]Akematsu and Tsuji (2012).

V. CONCLUSTIONS

This study aims ato providinge one clue tofor solveing athe global issue of the increase in patients with chronic diseases and suggests itthat the solution is telecare. The economic effect of telecare obtained here is not limited to an example in Japan alone. The research of the effect of telemedicine in other countries with macro data, representative macro approaches include those of [11] and [12], which used national cross-sectional data or panel data from OECD countries, respectively. Representative micro approaches include the following four papers. Evaluating 19 cases in Australia, [13] found that the cost-effectiveness of both telehealth and telemedicine improved considerably when they were part of an integrated use of telecommunications and information technology; [14] showed that advancements in e-Health transformed health care delivery and achieved such positive results as improving clinical decision making, increasing efficiency, and strengthening communication between physicians and patients; [15] found that an interactive telephonic support system which included coaching, education, and reinforcement modules reduced total costs for hospitalizations and emergency room visits by $5,271 per user per year; and [16] reported an average visit cost of $48.27 for a face-to-face home visit versus $22.10 for a

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virtual visit. Moreover, [17] conducted a systematic search of the literature and concluded that information technologies were effective in improving the quality and efficiency of care.

Regarding the studies that used micro data, there are similar projects with telecare in other countries. Scientific results have been obtained and it is possible to compare our results with those of other projects. Results obtained in other countries consist of the Kent Development Pilot in the UK and the VHA CCHT project in the US. The former studied the effect of telehealth on the number of inpatient days, general practitioners (GP), acute care, and others by experimental observation with statistical analysis[18]. This study compared outcomes at baseline and after six months with a focus on patients with COPD, heart disease, and diabetes. The authors concluded that telecare use resulted in a decrease in the number of home visits and GP surgery per participant, Accident and Emergency (A&E) visits of 0.5days, and inpatient treatment days of 1.5days. The results of the VHA CCHT project in the US are similar to those of the Kent study, that is, the number of inpatient treatment days was reduced by 25%, and the number of hospital admissions by 19%[19]. Thus the results of international projects were estimated mainly in terms of inpatient treatment days, not expenditures, and for all diseases, not only chronic diseases. This paper aimed to obtain results which are directly comparable with other studies. According to our results, the Nishi-aizu project shows a larger reduction in inpatient treatment days than the Kent project (3.3 vs. 1.5 days). On the other hand, the reduction of bed days is calculated as approximately 16.12% in this paper, which is smaller than that of the VHA project (25%).

The results obtained in this study show the importance of telemedicine. Japanese local governments implementing this system currently do not charge users for the service. The system is funded from tax money raised from local residents. For the initial investment for the in-home devices, servers, and network, local governments receive subsidies from the central government. The Nishi-aizu local government received funds from three different ministries. However, due to the current adverse economic situation in Japan, local governments can no longer rely on such subsidies, implying that the sustainability of telecare or e-Health is an issue that urgently needs to be addressed[8]. From a financial point of view, a new framework is required. Reimbursement through the medical insurance system, for example, is one possibility for increasing the use of telecare systems. Here, we provide an important basis for evidence-based public health policies.

It should be noted for further research that chronic conditions tend not to occur singly, and many patients have more than one at the same time. For example, patients with high blood pressure or diabetes are also likely to suffer from heart disease. This multiplicity of conditions hampers analysis. This paper examines single chronic diseases, and does not include multiplicity. In addition, neither does this study analyze how telecare improves these outcomes. In the telecare system introduced in Section II, telecare users become more concerned about their health condition when reviewing the data returned to them by the town health office, and make personal efforts to improve their health indicators. This assists in the prevention of chronic diseases. Although these psychological effects cannot be denied, more studies are required on the medical mechanisms by which telecare imparts positive impacts on health. These are remaining issues for future study.

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Using Models and Simulation for Predicting Efficiency as a Measure of Success of Different Telemedicine Deployments

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***Abstract*—The planning and development of large-scale telemedicine system implementations throughout Europe motivates the need for cost effective ways to predict the level of their success in each new context. The efficiency of the system and that of the work process involving it influence the success of any telemedicine implementation, determining whether the existing healthcare staff will be able to manage their workload in their available time. This paper demonstrates by means of examples how we could use observations from repeated simulations of a nurse working with a telemedicine system in different contexts, which may differ in several ways, to predict the efficiency of the work process. The examples presented in the paper are based on previous experience with the use of telemedicine systems in Lothian, Scotland.**

Keywords-telemedicine; telemonitoring; efficiency; scaling up; cognitive modelling; simulation

I. INTRODUCTION

Despite its potential advantages for patients suffering from long-term conditions, healthcare systems and the economy ([1]), the benefits of telemedicine in terms of patient care and costs have not been convincingly proven yet. Although many studies conclude that telemedicine is beneficial (e.g. [2, 3]), their evidence is often hard to generalise, as it is the result of small scale trials lead by enthusiasts [4, 5], and does not meet high evaluation standards [6, 7].

Several European countries are currently planning and developing large-scale telemedicine pilots, which will help assess whether telemedicine would work at scale. Two important examples are:

- The Renewing Health European project ([8]), which involves nine European regions in the provision of telemedicine services for large segments of the population suffering from chronic obstructive pulmonary disease (COPD), diabetes and cardiovascular disease;
- The ITTS (Implementing Transnational Telemedicine Solutions [9]) project partly funded by the EU Northern Periphery Programme, which involves partners from six Northern European countries and aims to facilitate transnational knowledge exchange for implementing telemedicine solutions at scale.

The UK is also planning a large-scale deployment of systems such as these through the Delivering Assisted Living Lifestyles at Scale (DALLAS [10]) programme. The Scottish government placed such nationwide deployment at the centre of Scotland's eHealth strategy [11].

Given the high level of risk associated with such projects, it becomes desirable to find cost-effective means to predict the success of telemedicine systems in different deployments, as this could influence the decision of investing into each deployment and help save resources. In a context characterised, on one hand, by a predicted shortage of human resources in healthcare and, on the other, by an increase in their workload due to an increase in the number of patients suffering from long term conditions ([1, 12]), the efficiency of a telemedicine system and that of the work process in which it is used are important factors for its success. We define efficiency here as how likely a healthcare professional is to care for her patients in her available time by using a work process involving the telemedicine system.

We have previously described a methodology and associated modelling approach which can be used for predicting the usability of telemedicine systems in different deployments [13]. We will only briefly summarize them in this paper, focusing only on the efficiency component of usability. Elsewhere, we have shown by means of examples how our approach would work for predicting the efficiency of the system when deployed in contexts differing in workload, user and system characteristics [14]. The differences we observed were only in terms of minutes, as actions on the system in question would take little time and rarely escalate to dramatic changes in the user's total time available. The very time intensive user work, which importantly influences the handling of her workload, lies outside of the system, within the work process. To cater for this conclusion, in this paper we exemplify how our approach can be used for predicting the efficiency of the work process involving the telemedicine system. While it may be hard for the naked eye to foresee how the user's time would vary in contexts which differ in several characteristics of her workload which may influence each other, we show how our approach can help in this respect to provide a clear indication of the time that the user would need within each context for managing her work safely. The examples contain invented facts and numbers, derived from previous experience with telemedicine systems in Lothian, Scotland ([15]). We also describe the study we commenced for validating our approach.

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II. THE PROPOSED METHODOLOGY AND MODELLING APPROACH

Our methodology is a guide for reusing models, which are found to reliably determine the efficiency of a work process involving a telemedicine system into a reference deployment site, for predicting the efficiency of the same work process if the system is deployed into a potential site, using only information about the characteristics of the potential site. Its main advantage is that it reduces the need for evaluating the system and work process into each new context, thus saving resources. It also helps analyse whether the work process would be manageable in potential contexts and explore what-if scenarios involving changes to the workload, user, process or system characteristics if not. A step-by-step description of the methodology is provided in Fig 1.

Although our methodology can be used with any type of modelling approach, depending on the level of perceived risk of the problem at hand, we have chosen to represent a work process by means of a user and system model which are run in parallel. The user model is a cognitive model inspired by the Icarus cognitive architecture ([16, 17, 18, 19, 20]), which receives as inputs a description of a user's profile in terms of goals, knowledge, skills as related to her work, and the time the user spends for performing actions on or outside of the system. We have chosen cognitive modelling due to the cognitive nature of nurses' medical work ([21], [22]). The system model is a basic labelled transition system, which receives as inputs what the system presents to the user or stores internally at one time, how this changes as an effect to user actions on it, and the time it takes to make such changes (waiting time). The 'run of the model' means the parallel run of the user and system model, simulating a user using the system and doing any actions external to it. It takes as inputs a new workload and other characteristics of the work environment, which can be either constants (the same on every simulation run e.g. the number of patients to be monitored) or numbers drawn from probability distributions (e.g. for the values of readings). A high enough number of runs helps to obtain the expected distribution of the time spent by the user in achieving her goals (doing her work) in one deployment site. By changing the characteristics of the workload and/or the inputs to the models (e.g. to reflect changes in user skills, way of doing things or system design) we can model potential deployments, which can differ in several ways, sometimes interacting with each other, to the reference one. By running another high enough number of runs, we can obtain predictions of the efficiency of each potential context, unobvious to the naked eye, and useful for the analysis of whether work would be manageable there, as we will exemplify below.

III. EXAMPLES

Let us consider the case of a hypertension monitoring work process performed by nurses with the help of an online telemonitoring system, in which the nurses follow the steps from below (derived from previous experience [15]):

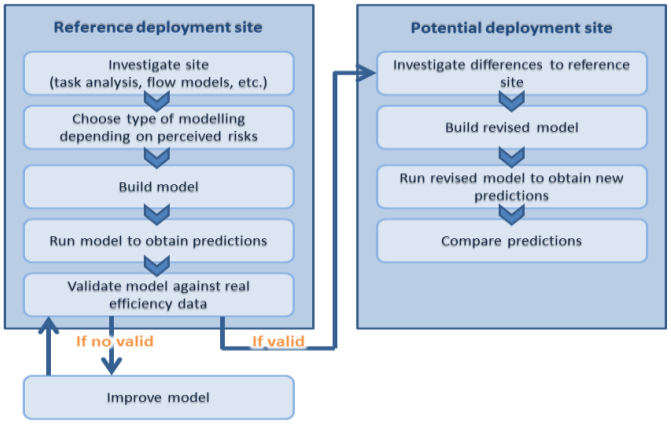

Figure 1. The methodology.

From the table of patients from the system's homepage, the nurse selects one who is flagged up (as having the last systolic-diastolic pairs as exacerbations) by choosing an appropriate action from a pop-up box, which takes her to the patient's details page. Here, she can see the patient's demographics, contact details, and last two days of systolic-diastolic pairs of readings. If the readings are concerning, the nurse clicks on a button to go into the patient's extended (seven day) details. Next, she needs to go into the electronic health record, on a separate system, to check the patient's medical history. If the patient's condition seems to be worsening, the nurse may decide to call her to check on her state, gain any additional information and give her advice. For doing this, she needs to go back to the patient's details page and retrieve her phone number. Following this call, if the nurse concludes that the patient needs an appointment with her GP (General Practitioner), she will retrieve the GP's phone number from the same page and call the GP, also passing on the medical information gained. Even if the patient did not require a call or an appointment, the nurse will next enter her conclusion as a note in a form provided on the patient's details page. Following this step or if the patient's condition noticed from the extended details page and history was not worsening, the nurse returns to the homepage. As there are no options in the system to acknowledge who has been checked, she writes the patient's name down before selecting the next flagged up patient in the list, scrolling down to retrieve her first if necessary. The nurse finishes her work when all of the flagged up patients have been checked.

Let us consider for a **first scenario** a medical practice which has recruited 20 patients for being monitored by using the telemonitoring system, and where a nurse's time allocated for the monitoring work is 2 hours (many practices in the UK allocate a fixed amount of time from a nurse's shift for telemonitoring work). Let us suppose that, according to our analysis of the context, we found that the patients' reading criticality is characterized by a mean of 30% and standard deviation of 10%. While for keystroke-level actions we use the time from the Keystroke-Level Model (KLM [23, 24]), we define the following times for actions performed outside of the system:

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- Calling up patients: the nurse will dial the number in a time characterized by a mean of 8 seconds and standard deviation of 1 second. She will hold on the phone for 10 seconds. Patients pick up the phone in a time characterized by a mean of 7 seconds and standard deviation of 1 second, so the nurse will not miss any patients in this context.
- Speaking with the patients will take the nurse a time characterized by a mean of 8 minutes and standard deviation of 2 minutes.
- Calling up and speaking with the GP will take the nurse a time characterized by a mean of 3 minutes and standard deviation of 30 seconds. Please note that here we have not broken down the steps of performing the call as for patient calls from above, as we consider that the GPs will always pick up and that there is efficient communication set up between the nurse and the GP.
- Writing down names takes the nurse a time defined by a mean of 5 seconds and standard deviation of half a second.
- Checking the electronic health record (which is a separate system, and so we are not considering it within the system model) takes a time defined by a mean of 3 minutes and standard deviation of 20 seconds.

Also, let us consider that an analysis of the practice's statistical data on who has been called and how often, we found that out of the patients whose medical history the nurse checks, those who need a call are characterized by a mean of 50% and standard deviation of 10%. Also, out of the patients whom the nurse has called, we find that those who need an appointment with their GP are characterized by a mean of 30% and standard deviation of 10%. This data is used to simulate a nurse's decision of when to call the patient and GP.

We implemented the above scenario by using our modelling approach, and performed 200 runs to obtain a prediction of the distribution of the time it takes for the nurse to monitor all of the patients who are flagged up. A representation of the results is provided in Fig. 2.

The figure predicts that the nurse will always manage her work within the 2 hours (7200 seconds) allocated for it- in ideal conditions, where there are no interruptions, the latest time she will always finish is 7000 seconds- 3 minutes earlier than the deadline. Moreover, she would very rarely need the time between the last 20 and the last 3 minutes (only once in 100 work sessions would she need more than 6000 seconds- 1h 40min) and she would rarely need the time between the last 37 and the last 20 minutes (only 2.5 times in 100 work sessions would she need between 5000 seconds- 1h 23min, and 6000 seconds- 1h 40min). This analysis, together with an analysis of cost and of the nurses' workload for other duties, could aid in the reconsideration of the time allocated to them for the monitoring work. The two hour time allocation already offered to them is predicted to be the safest option, as the nurse would always manage all of the patients in this time. Nevertheless, if cost is more of a concern and/or the nurse's time is critically needed for other duties, offering each nurse 1h 45min, or even 1h 30min would be better options, and still safe enough, as in very rare cases would the nurse have to exceed them.

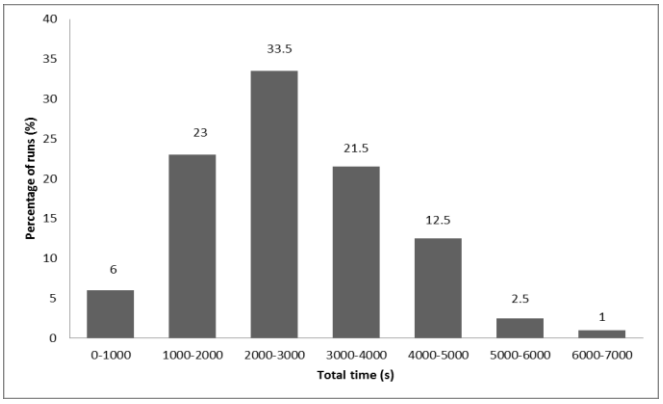

Figure 2. First scenario.

We suppose that the efficiency results in the first scenario correspond with experience there. Let us next consider that there are plans to deploy the system into two potential sites, in both of which a nurse will deal with double the number of patients than in our reference site (40), and which, it turns out, differ in various other ways. We would be interested to estimate how much time nurses should have allocated for the monitoring work in each of the sites.

The first potential deployment site (**second scenario**) has decided to recruit double the number of patients than the reference site, but these patients are less sick- the criticality of their readings has a mean of 20% and standard deviation of 5%, and the nurses are more likely to refer called up patients to their GPs- out of the patients who have been called up, those who are to be set up an appointment are characterised by a mean of 50% and standard deviation of 10%.

Although one would normally expect that double the patients would mean double the time spent monitoring them, our variations on the reading criticality and percentage of patients to require an appointment with the GP make our conclusion less clear. It is in such cases that our modelling approach can be of help. By reinstantiating our models with the new inputs and running another 200 simulation runs, we obtain the graph presented in Fig. 3.

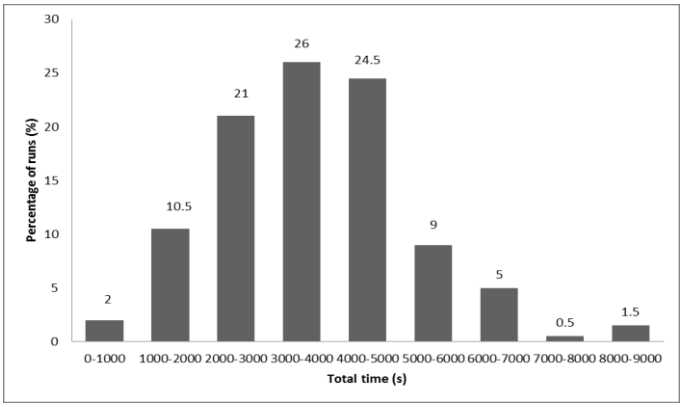

Figure 3. Second scenario.

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The graph predicts that the decrease in the criticality of the patients' readings has mostly compensated the doubling of the number of patients and the increase in the percentage of called patients who need a referral, as the maximum time that the nurse would spend in this scenario is 9000 seconds (2.5 hours), only half an hour more than in the first scenario. Moreover, the nurse would need the last 17 minutes of this time extremely rarely (1.5 cases in every 100 work sessions), and the last 33 minutes very rarely (in 2 every 100 work sessions). This predicts that the safest time the nurse should have allocated is 2 and a half hours, but that 2h 15min and 2 hours would be more economical, and still safe enough, options. Our approach thus helps explore how the different inputs to the models interact to influence the total time.

The second potential site (**third scenario**) has also decided to recruit double the number of patients than the reference site, and these patients are sicker- the criticality of their readings has a mean of 40% and standard deviation of 10%. For fear that they would not be able to manage their work, the nurses here have decided on some simple questions to always ask patients whenever they call them, which would lead to less time spent during phone conversations with them- the new time is characterised by a mean of 6 minutes and standard deviation of 1 minute and 20 seconds.

Although double the patients and sicker patients would intuitively lead to more than double the time spent monitoring them as compared to the reference site, the fact that nurses speak less time on the phone with patients, where phone conversations are the most time consuming external action, will compensate some of the time, but it is difficult for the naked eye to decide how much. By reinstantiating our models and running another 200 simulation runs for this new scenario, we obtain the graph from Fig. 4.

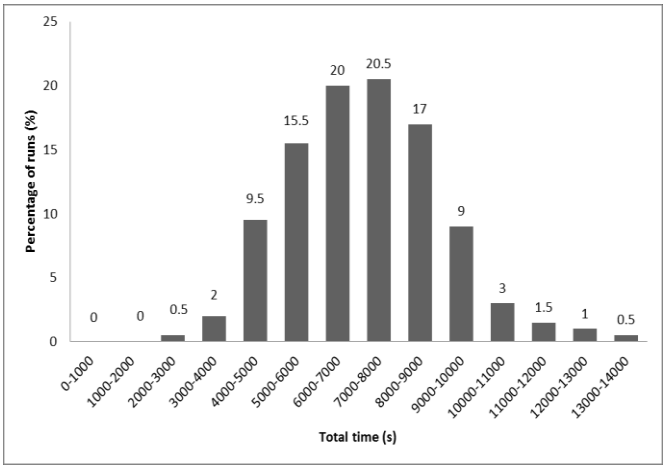

Figure 4. Third scenario.

The graph predicts that the introduction of the nurses' call protocol does not compensate greatly the time influenced by the more numerous and sicker patients, as nurses would still maximally spend more than double the time of the reference deployment site monitoring all of their patients. Nevertheless, the graph predicts that nurses would very rarely (in 3 every 100 work sessions) need more than 3h 3min (11000 sec) to handle all of the patients. Therefore, although an ideal, safest time to offer them would be 4h (over 14000 sec), 3h 30, 3h 15min and 3 hours would be more economical, and still safe enough, options.

IV. START ON VALIDATION

To validate our work, we will use our methodology and modelling approach to help predict the efficiency of a monitoring work process for a new telemonitoring system introduced in Lothian, Scotland. We are currently working on iteratively improving our modelling approach until it can be used to reliably predict the efficiency of the work process for deployment sites where the system is already being used. To do this, we are conducting observations of users monitoring patients using the system, and using data from system logs, other system documentation and the practices' statistical data, which helps us both obtain inputs for our model, and gain an understanding of the true efficiency of the work process to test the results of running our model against. Once our modelling approach is found to be reliable enough, we will gather data about potential deployment contexts and use our approach to predict efficiency there. A new evaluation of the efficiency of the work process in these contexts, once the system has been deployed and users have gained some experience with it, will reveal whether our approach is successful. The system is being used for monitoring two long-term conditions, by users with different roles and experience (non-clinical call centre staff vs. clinical users- nurses, physiotherapists, GPs, more or less computer literate or used with the system), which will help us also explore how efficiency is influenced by such aspects.

V. RELATED WORK

From a methodological standpoint, although we have not found any literature describing a methodology similar to ours, the areas of performance modelling and business process change management are the closest. In the area of performance modelling, the most relevant work is that by Bailey and Snavely ([25]), as it proposes using models for the 'what-if' exploration of how, in this case, the performance of large-scale scientific programs, is affected by systems of different sizes and different jobs. Like us, they stress that such an approach helps reduce the need for more costly evaluation, and inform the choice of a system. The authors of SAP (Systems, Applications and Products in Data Processing [26, 27]) combine the two areas to propose an approach allowing the exploration of 'what-if' scenarios for business process models. The purpose of these papers is to explore changes to one deployment site, while that of our work is to compare sites differing in several aspects which may influence each other.

From a work process standpoint, time and motion is considered the most reliable method for analysing the impact that the introduction of health information systems in hospitals would have on the workflow of health professionals [28]. Recent years have seen a surge in the use

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of time and motion studies in health informatics, due to some pioneering papers ([29], [30]), the development of a data acquisition tool ([31], [32], [33]) and steps towards methodological standardisation [28]. Through continuous observation of clinician work, time and motion can help deduce important aspects of the efficiency of work processes involving a health information system: the time it takes to perform each type of task, where inefficiencies may lie, the effect of interruptions, collaboration with colleagues and multitasking.

There is of course a lot of literature on using models for predicting the efficiency of a system or process in terms of execution time, most notable being the work on the GOMS (Goals, Operators, Methods, and Selection rules) family of models [34]).

Our work is not intended to compete with model-based evaluation approaches, and it is not currently evaluating the efficiency of a single work process in the same depth as the time and motion method. Its strength does not lie in the prediction of efficiency within a single context, but in being used for analysing efficiency in contexts which may differ in several ways, including scale, without the need for costly evaluation with users, and in the area of telemedicine where there is a strong motivation for such an approach.

VI. Discussion, Conclusion and Future Work

We have briefly described a methodology which can be used for predicting the efficiency of a work process involving a telemedicine system in different deployment sites, and proposed a modelling approach to be used with it. We have exemplified them in action for providing an indication of the distribution of the time needed by a nurse performing monitoring work using a telemonitoring system, and showed how these results can be used for deciding what would be a good time limit to give to nurses such that their work is safe enough. Given considerations of cost and resources, its findings can lead to a decision of whether the work in the potential site is manageable, before any resources are wasted in deploying the system in that site. Should the work be found unmanageable, we could use it to answer 'what-if' questions about the effects of potential solutions: changing the characteristics of the workload, user, process or system.

Although for contexts which differ slightly our approach might not be necessary, as the practicality of deploying the system there would be clear, there are many contexts where differences are complex and interact with each other where our approach could be useful. These contexts could be real ones where the system is planned to be deployed, or hypothetical ones- e.g. would monitoring work still be manageable if the system is to be used during an epidemic, with more and sicker patients?

We have also described the validation work that we have started for our approach. The result of the current phase will be an improved modelling approach, including changes both to its logic and the specification of the models, and a good understanding of its pros and cons. The next step is to check whether our approach will provide good efficiency predictions in potential deployment sites.

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Security Challenges and Solutions for Telemedicine over EPON

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Abstract— **Keeping data integrity and privacy is a major design concern for telemedicine applications, where sensitive and personal information are collected and disseminated over telecommunication system. For this reason, this study discusses the network characteristics and security issues in the Ethernet Passive Optical Network (EPON), which is responsible for conveying traffic between the hospital or healthcare centers and patients. Subsequently, different types of security challenges are classified and a survey of solutions is presented. The purpose of this research is to highlight the security issues in EPON system as a transmission method of telemedicine services and any person will be aware of the potential attacks during data transmission.**

Keywords-security challenges; EPON; telemedicine.

I. INTRODUCTION

Security issue is a primary concern for the telemedicine application, where confidential data are exchanged between healthcare providers and patients. A telemedicine communication system consists of three principal divisions: a hospital service/data center, a transmission and distribution system, and patient home environment. The hospital service/data center provides medical instructions and assignments to individual patient, meanwhile it stores patient personal information and medical records/documents in the data center. The transmission and distribution system connects the hospital and the patient at home and exchanges data (such as messages, files, videos, and so on). Telemedicine applications and devices are used by patients at their homes, so that they can remotely communicate with doctors and get correct and necessary medical advices. This work studies the usage of optical access network for the telemedicine communication system for data transmitting and distributing.

Delivering data over optical fiber links becomes the most prominent way in the access networks. Presently, the Fiber to the Home (FTTH) are being deployed to the subscriber by a strong worldwide push: in United States, the annual growth rate was 112% during September 2006 to September 2007 and in Denmark, the FTTH subscribers increased 90% in year 2008 [1] [2]. The cost effective Ethernet Passive Optical Networks (EPON) with point-to-multipoint architecture is the prevalent solution to FTTH. The typical EPON system is a tree structure consisting of an Optical Line Terminal (OLT) located at a central office, a *1:N* splitter, and multiple Optical Network Units (ONUs) at the end users' premises.

The telemedicine communication system relies primarily on health information security and confidentiality. Many countries have legislations with appropriate confidentiality policies, individual identification procedures and practices, so that information access is strictly limited to authorized person with the consent of the patient [3]. In order to design a completely secure telemedicine system, security must be integrated into every node and each element is responsible for ensuring information security. This dictates that data security is related to the entire communication system.

Currently, various research projects begin to investigate the potential security risks on different aspects in the telemedicine system in order to minimize the consequential impacts on the privacy of the whole system and patient personal information. The telemedicine communication system contains different kinds of hardware equipments, software applications and transmission mediums. Therefore, the security and privacy issues are identified and discussed from different aspects. At the software level, Baker and Wallace [4] explore the risks of hacking in software and computer systems and tempering user database, where data can be stolen or altered. At the network level, two network technologies, Ethernet and mobile network, have been studied and discussed regarding to the security aspect, respectively Kiravuo et al. in [5] and Boukerche and Ren [6]. In [7], besides the manmade events, Carvalho and De Souza worked on network resilience and path protection in order to reduce the risks caused by natural effects or earthquake.

This paper focuses on the security issues in the stage of data transmission and distribution. On the basis of EPON, it is vitally important to ensure that any data transmitted over optical channel, for example, medical history of a patient, cannot be leaked out and used to identify a person.

The rest of this paper is organized as follows. In section II, we first describe the basic architecture and operation processes of EPON. We present the security challenges in EPON and give a survey on proposed solutions in section III and section IV, respectively.

II. EPON SYSTEM

In an EPON system, one OLT is functionalized as an administrator connecting multiple ONUs in the subscribers' locations. IEEE 802.3ah Task Force [8] specifies the physical layer and MAC layer characteristics of EPON.

As shown in Figure 1, we consider an EPON system consisting of *K* ONUs that connect to a central control station, OLT, via the optical link. In the downstream direction from the OLT to the associated ONUs, data are broadcasted to each ONU in a point-to-multipoint architecture. On the other hand, it is a multipoint-to-point architecture in the upstream direction from the ONUs to the OLT.

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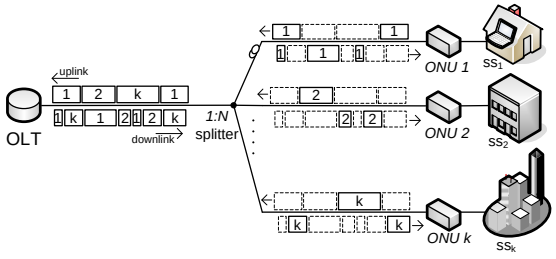

Figure 1. EPON system: upstream (multi-point to point) and downstream (point to multi-point) transmission.

Multiple ONUs share the optical bandwidth with Time Division Multiplexing (TDM) technique [1]. The OLT allocates upstream bandwidth among the ONUs and each ONU transmits packets in dedicated time slots in order to avoid collision. Two processes are performed: the auto-discovery process and the normal process.

- During the discovery process, the OLT searches for ONUs, authenticates and registers attached ONUs, and calculates the Round Trip Time (RTT). After discovering and registering the connected ONUs, the OLT sets up an entry table, which contains the ONU Logic Link Identification (LLID) and RTT values.
- A key perspective of the normal process is the ability to assign bandwidth and schedule transmission for all registered ONUs in a manner of fairness and without conflict. The OLT polls registered ONUs and assigns time slots either statically or dynamically based on the resource requirement negotiation.

III. SECURITY CHALLENGE IN EPON

In a communication system for telemedicine applications, security management is applied for keeping the data integrity without being tampered, patient privacy and confidentiality without being released or retrieved, and access control without being unauthorized accessed. In this paper, EPON is used for data transmission for telemedicine service and we study communications security challenges in EPON. EPON have security threats and vulnerabilities that are experienced in the general network. Meanwhile, there are special attacks due to transmission characteristics in EPON, for example, network topology, control protocol, communication equipments as well as network access ports [9][10].

A. Potential Security Risk with EPON Topology

Security depends highly on the configuration of network architecture. Unlike a peer-to-peer network, where a trust between a server and a user is normally existed, EPON system with a point-to-multipoint structure is vulnerable to intruders. In EPON, downstream traffic is broadcasted and upstream bandwidth resources are shared by multiple users. Besides, we cannot assume a fixed topology, because the registration of ONUs is dynamic and an ONU may leave or join the network at any time. The potential threats, eavesdropping and Denial of Service (DoS), are possible occurred due to the point-to-multipoint topology.

- *Eavesdropping*: ONUs can receive all downstream traffic by simply disabling the address/ID filter and freely receiving data destined to other ONUs. Since it is difficult to detect such an attack at OLT, a malicious ONU can eavesdrop traffic without being noticed and interrupted for 24 hours per day.
- *Denial of Service (DoS)*: the upstream bandwidth is distributed among several users. Each ONU needs to transmit in upstream direction by complying with the assigned timeslots. If a misbehaved ONU on purpose transmits outside the schedule, it can consequently cause collision with the ongoing transmission from a legitimate ONU, and even worse, it can block the channel with large amounts of traffic.
- *Theft of Service (ToS)*: ToS is threat that is common to all networks. One malicious subscriber attempts to impersonate another legitimate ONU, by forging all useful ONU information including LLID, MAC address, and so on. Since the LLID is the identity assigned during the registration process and used as a digital signature during the normal process, the malicious subscriber obtains bandwidth without any access cost by a forged LLID.

B. Potential Security Risk with Control Protocol

The Multi-Point Control Protocol (MPCP) as the control and signaling protocol is defined in EPON standard. After the registration process, the OLT communicates and schedules transmission timeslots to ONUs based on their assigned identifications, LLIDs. During the registration process, a potential threat is called *impersonation*.

The malicious user has opportunity to collect information about the target ONU such as its LLID and MAC address and masquerade as a legitimate ONU to use network resources with free charge. Even worse, the attacker can seriously invade other's privacy by forging wrong information and transmitting on behalf of another ONU.

IV. SURVEY OF SOLUTIONS FOR EPON SECURITY

EPON system has unsurpassed advantages in comparison to the data transmission over copper wires or air interfaces. However, protecting the patient's privacy and secure the transmission system becomes an important concern due to its topology. With properly designed security management can reduce the risk of security attacks even though they may not be eliminated. Based on the potential threats and security challenges in EPON, various solutions are proposed to answer specific security requirements.

A. Data Cryptography

Cryptography is the process of hiding the original data in a serial of meaningless scrambled code during transmission. At the receiver node, data is deciphered and converted back into the original information. Due to the point-to-multipoint network topology, eavesdropping is possible in the downstream direction by simply changing a registered ONU configuration into the promiscuous mode. Thus, the downstream data need to be encrypted to safeguard the information.

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The data encryption for 1G-EPON is undefined in original 802.3ah-2004 standard [8]. Later in 2008, the YD/T 1771-2008 Technical Requirements for Access Networks - Interoperability of EPON Systems uses the triple churning algorithm [11]. When evolving into 10G-EPON, an advanced encryption method, Galois Counter Mode (GCM) is adopted as described in the IEEE MAC security (MACsec) standard, 802.1AE [12]. GCM provides high security by using 128 bits Advanced Encryption Standard (AES) in counter mode and supports high speed data transmission due to the pipeline architecture of AES [13]. An alternative solution is the multi-byte churning encryption algorithm, which increases the key length in order to improve the security level and can be implemented at fast transmission speed [14].

In order to analyze the alternative encryption algorithms proposed for EPON system, we compare the single / triple churning algorithm and the AES algorithm in terms of speed, complexity and security strength (shown in Table 1). The churning algorithm is used to protect data confidentiality by scrambling function. The single churning algorithm uses a 24-bit key code. The implementation is simple and high speed. Triple churning algorithm is expanded on the basis of single churning algorithm in order to increase the security level. The key length is increased to 48 bits. AES is a symmetric-key encryption algorithm, where the same key is used for both encryption at the transmitter and decryption at the receiver. In EPON standard, GCM uses the AES with a key length of 128 bits. Designed as a pipelined architecture, AES is suitable for high-speed hardware implementation and meets the operation requirement in the10G EPON systems.

TABLE I. COMPARISON OF ENCRYPTION ALGORITHMS IN EPON

	Single Churning	***Triple Churning***	***GCM with AES***
Speed	Fast	Fast	Fast
Security level	Low (14 bits key)	Low (48 bits key)	High (128 bits key)
Implementation Complexity	Low	Low	high

B. Authentication Protocols

An authentication protocol is used to verify an identification of a node as a valid member in the network. Same as date encryption, node authentication is also a main defense again attack. EPON topology is open and dynamic. In the upstream direction, an authorization and authentication mechanism is required to ensure the communication reliability and to avoid the impersonation from illegal masquerading users. A new ONU must be mutually authenticated during the auto-discovery process.

Given various authentication protocols have been proposed [10], ONU authentication and secure provisioning are presented in the latest IEEE 1904.1-2013 standard for Service Interoperability in EPON (SIEPON) [15] [16]. To deal with both legacy 1G-EPON and the next generation 10G-EPON, IEEE 802.1X-2004 and IEEE 802.1X-2010 are defined as ONU authentication mechanisms, respectively. Both two generations are based on Extensible Authentication Protocol (EAP) methods:

- *IEEE 802.1X-2004 and EAP-MD5*: The EAP-MD5, defined in RFC 2284, is known as simple with very light and fast processing. The principle is in a challenge-response principle. The OLT as an authenticator sends an EAP request. The ONU as a supplicant replies with its identification in a response message, which is relayed to an authentication server. The OLT then sends an EAP challenge packet of type MD5 challenge to the ONU. After calculating a MD5 hash based on the challenge, the ONU returns a response containing the hash value. On the server side, the same hash computation is performed and two values are compared. The authentication is success if two hash values are identical, otherwise, the authentication fails.
- *IEEE 802.1X-2010 and EAP-GPSK*: the authentication scheme, EAP Generalized Pre-Shared Key (EAP-GPSK), is an advanced technique to obtain mutual authentication and key agreement between the authenticator and supplicant *[17]*. For the authentication in the 10G-EPON, an OLT starts with an EAP request message containing its identification ID_olt. The applicant ONU responses with its own identification, ID_onu. The OLT sends ID_olt, a random number RAND_server, and a list of supported ciphersuites, CSuite_List. The ONU then requests with ID_onu, a random number, RAND_onu, a repeat of received parameters of the OLT, the selected ciphersuite and a Message Authentication Code (MAC_onu) that is computed based on all the transmitted parameters. The OLT verifies the received MAC_onu code and the consistency of parameters. In case of successful verification, the EAP server computes a MAC_olt over the session parameter and returns it to the peer. The peer verifies the received MAC_olt code, and consistency of parameters. If the verification is successful, ONU replies with a message that can optionally contain the peer's protected data parameters. Then, the OLT sends an EAP Success message to indicate the successful outcome of the authentication. The keys used to compute MAC at the OLT and ONU are both derived from a Key Derivation Function (KDF), which based on a long-term pre-shared key. Both the server OLT and the peer ONU are authenticated by using the MAC key code.

During the authentication process, three types of ONU identification are used: MAC address based, logical ID based and hybrid authentication. The first method uses information provided by ONU during the auto-discovery process. The second method requires a provider defined logical ID, which is manufactured into an ONU device. In the hybrid mode, if the MAC address based authentication fails, the OLT then initiates to the logical ID based authentication [16].

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C. Security Enhanced Communication Technologies

PON technology is developed with the aims of increased data rate, increased range, reduced cost and reduced energy consumption. The following technologies improve network performances and profits. Meanwhile they affect the security properties of EPON system in term of involving multiple wavelengths, operating at fast speed, and deploying a different multiplexing method.

- *Wavelength Division Multiplexing (WDM) technology*: The straight way to improve network security is to setup a point-to-point communication between the server and the client. By assigning traffic on links with different wavelengths, the WDM-PON allows the OLT exchange data with each ONU at a unique wavelength.
- *High speed 10G-EPON*: The churning encryption scheme has drawbacks such as short key length and low operation speed. With the upgrading to 10G EPON, GCM is deployed to ensure data security as well as to guarantee the information reliability. By combining Galois field message authentication code (GMAC), the method realizes authentication process and can be used as an incremental MAC [13].
- *Optical Code Division Multiple Access (OCDMA) technology*: While being successfully developed in wireless communication, the OCDMA introduces this concept into fiber optic communication systems, where encoding and decoding operations are performed in optical domain. Advantages of using OCDMA include realizing higher spectral efficiency, providing higher system capacity and enhancing security. In OCDMA-PONs, different users are assigned orthogonal codes, with which each user's data are encoded/decoded with an optical pulse sequence. Thus, this technique provides asynchronous communications and security against unauthorized users [18] [19].

D. Security Enhanced Communication Devices

Using a conventional TDM PON, security enhancement can be introduced to the physical devices, OLT and ONU. In [20], authors demonstrate the physical security enhancement from using a pair of matched tunable lasers in OLT. A unique point-to-point link is created between the OLT and the destination ONU since the tunable laser transmits each frame with a unique identifying code and each ONU is also assigned with a unique wavelength.

E. Security Mechanism in Hybrid Network Topology

A telemedicine communication system is composed of different communication technologies instead of a solo transmission links. EPON is responsible for delivering traffic to the users' premises. The last-mile can be accomplished by using Digital Subscriber Line (DSL) or Wireless Local Area Network (WLAN) technologies. Research about a unified security framework for integrated technologies is ongoing. In [21] [22], authors discuss about the integrated authentication process and data encryption scheme in the combined EPON and wireless networks.

V. Conclusion and Future Work

The major strengths of EPON are its high data rate and low cost. They are also the causes of its prevalence in the access network. Nowadays, security issues for EPON system become a serious concern, particular for transmitting patient medical histories and hospital health records. Concerns are raised about patient privacy and data security due to the broadcast characteristics in EPON. This paper discusses several research efforts, which have been trying to address the security issues in EPON. The challenges are addressed in order to point out the secure weakness caused by EPON structure, protocol and devices. Hence, this work shows that as the transmission channel is vulnerable, potential attacks can be possible to harm the entire telemedicine system. This paper further presents a survey of existing solutions to deal with data confidentiality, authentication, access control and integration with other network technologies. Through our study, we showed different aspects and concerns for a security framework for the telemedicine system over EPON. Future work will consider simulation and result analysis for the discussed solutions.

Acknowledgment

The authors would like to acknowledge the support by the Patient @ Home project - Danish welfare technological research and innovation initiative project [23].

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Expectations of Middle-aged and Elderly Persons towards using Telecare Technologies and eHealth Applications in Primary Care

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***Abstract*—The aim of this study was to investigate general expectations of middle-aged and elderly persons towards using care technologies and eHealth applications in primary care. Participants were recruited at an event about health and exercise for elderly people. Persons aged fifty years or older and who were able to provide informed consent were eligible for inclusion. A cross-sectional mixed method approach was used; participants could choose whether they wanted to participate in this study by filling out a questionnaire or by participating in a short structured interview. Fifty-seven participants rated 22 items of a questionnaire on a five-point Likert scale. The questionnaire consisted of seven subscales: experiences with general technology, experiences with care technology, perceived barriers, perceived benefits, external cues to take action, attitude towards using and intention to use technologies in primary care. Furthermore, six interviews were conducted. The questionnaire revealed that participants had a positive attitude towards using technology in primary care and that their behavioral intention to use technology in primary care was high. In addition, the mean score of perceived benefits was higher than the mean score of perceived barriers. Time-saving, comfort and a higher degree of expected safety were the most frequently mentioned advantages in the structured interviews. The lack of personal contact and usability difficulties were the most frequently reported disadvantages of care technology. Based on the results it can be concluded that middle-aged and elderly persons have a positive view towards primary care technologies. However, the mentioned barriers should be taken into account during the implementation and development of technologies in primary care.**

Keywords-eHealth; telecare, expectations, intention to use, primary care, middle-aged adults, elderly persons

I. INTRODUCTION

The number of elderly persons is increasing. The number of persons aged sixty years or older tripled between 1950 and 2000, and is expected to increase threefold again by 2050, up to nearly two billion [1]. Mainly as a result of this, the number of chronically ill patients is increasing. Parallel to these increasing numbers, there is a relative decrease in the number of staff working in the healthcare sector. Due to these reasons, a fundamental change is necessary in the healthcare process [2]. Telecare technologies and eHealth applications could facilitate a shift from intra-institutional care to more home-based care. It is expected that these technologies, which support self-care and self-management, can reduce healthcare costs and can improve health outcomes among chronically ill patients [3, 4].

Despite these positive expectations, a recently published review by Peeters et al. [5] showed that most studies which explored the effects of technology in home-based care were pilot-studies with small samples e.g., [6-8]. In addition, the majority of these studies had short durations with only one follow-up assessment and no control group. Although positive effects of technology in primary care are expected, up until now there is not enough convincing evidence for these effects. Furthermore, many studies explored the effects of care technologies in controlled conditions. Due to this, it is difficult to guarantee that these technologies will also work in real life environments, when embedded in daily care procedures. Large-scale studies in care practices are needed to investigate the effects and consequences of using technology in primary care on a general level.

Before large-scale studies in care practices can be set-up, it is important to investigate users' needs and expectations regarding the use of telecare products and services, since taking these into account during the development and implementation process will increase the level of user satisfaction and user acceptance [9-12]. However, studies exploring patients' needs and expectations towards large-scale use of telecare technologies and eHealth applications in the Dutch primary care setting are scarce.

Middle-aged and elderly persons are a major group of primary care users. Therefore, the aim of this study was to investigate general expectations of persons aged fifty years or older towards using telecare technologies and eHealth applications in primary care. This provides important input for the implementation of care technologies in primary care. Since the data collection is still ongoing, this paper will discuss the preliminary results of this study.

The paper describes the methodology (Section II) and presents the preliminary results of this study (Section III). In Section IV the results are discussed and the conclusion and future work are presented in Section V.

II. METHODS

This methods section describes the recruitment of the participants, setting, study procedure, measurements and analyses which were utilized for this study.

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A. Design, setting, and participants

The study has a cross-sectional, mixed methods design. Questionnaires and structured interviews were used for data collection.

Participants were recruited at an event regarding health and exercise for elderly persons that took place at a large sports hall in Nederweert (the Netherlands). Inclusion criteria were: fifty years or older and Dutch-speaking, since the information letter and questionnaire were in Dutch. Exclusion criteria were: serious visual impairments for the study with questionnaires, and serious hearing impairments for the interviews.

At the stand at the event the researchers showed movies and presentations about examples of telecare technologies and eHealth applications. In addition, the stand was decorated with posters which presented several examples of primary care technologies. Furthermore, two Ipads with a medication management app, a physical activity monitoring and feedback system for chronically ill patients [13, 14], a physical functioning monitoring and feedback system for elderly persons [15] and an online platform for care and wellbeing for elderly persons (including functions regarding social contacts, comfort, and health and safety) were demonstrated. The study was carried out in the first week of October 2013.

B. Study procedure

Visitors of the event were asked by the researchers whether they wanted to participate in this study by filling out a questionnaire or by participating in an interview. If people were willing to participate, they signed an informed consent form after reading the information letter. In both the questionnaires and the interviews everyday language was used.

On the first page of the questionnaire several examples of telecare technologies and eHealth applications in primary care were described. This was done to ensure that participants were aware of the following possibilities that such technologies provide: planning an online appointment with a general practitioner, online video consult with a general practitioner, online coaching program to quit smoking, online revalidation program, physical activity monitoring and feedback system, medication management program, and Ambient Assisted Living (AAL) motion tracking systems. Next, participants filled out their demographical data. Then, they filled out questions regarding their expectations of technologies in primary care. Filling out the entire questionnaire took approximately fifteen minutes.

People who preferred to participate in an interview sat down with the researcher at a separate/quiet corner of the stand. The interviews took approximately fifteen minutes and were recorded with a voice recorder.

C. Measurements

Information regarding demographical data (gender, age, highest level of education, marital status and living situation) and health status (general health status, physical fitness, (chronic) diseases, and illness in last three months) were collected using the first part of the questionnaire.

The second part of the questionnaire was largely based on previous research regarding the possibility of using concepts of the Health Belief Model to predict the intention of the general population and chronically ill patients to use telecare products and services [16, 17]. The items were translated into Dutch and adapted to the topic of this study. In addition, several items about technology usage were added. The adapted questionnaire consisted 22 items divided over seven subscales: general technology usage (3 items), experience with technology in healthcare (1 item), perceived benefits (4 items), perceived barriers (3 items), external cues to take action (4 items), attitude towards using (3 items) and behavioral intention (4 items) to use telecare technologies and eHealth applications in primary care. An overview of the items is provided in Table I. Participants rated each item on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). In addition, the following open-ended question was added: “What kind of technologies in primary care would you like to use at home, and why?”. Participants could write down additional comments at the end of the questionnaire.

To gather more in-depth information about expectations of technology in primary care, interviews were conducted. The structured interview consisted of the following questions: “Do you use a lot of technology in daily life?”, “When I speak of technologies in primary care, what kind of technologies do you think of?”, “What are the advantages and disadvantages of technology in primary care?” and “What kind of technologies in primary care would you like to use?”.

D. Analyses

The scores of the questionnaire were quantitatively analyzed. First, mean scores and standard deviations of the seven different subscales were calculated for the whole study sample. Furthermore, the spread of participants on the different subscales was explored using boxplots. Moreover, differences between men and women, participants aged below 65 years and aged 65 years or older, and participants with or without chronic diseases were investigated for each subscale independently. In addition, differences between participants with high general technology experiences (mean scores of 3.5 or higher on that subscale) and low general technology experiences (mean scores below 3.5 on that subscale) were explored on experiences with technology in healthcare, perceived benefits, perceived barriers, external cues to take action, attitude towards using and intention to use. These differences were investigated using independent sample t-tests. The statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) 21.0 for Windows [18].

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TABLE I. ITEMS OF THE QUESTIONNAIRE

General technology experience
1. I use many technological devices in daily life (think about computers, mobile phones, tablet etc.).
2. I like to discover new technologies.
3. I have mainly positive experiences with technological devices.

Experiences of technology in health care
4. I have experience with technology in health care.

Perceived benefits
5. I think that using technologies in primary care are helpful in monitoring my health.
6. I think that using technologies in primary care increases my safety in daily life.
7. I think that technologies in primary care can enhance my level of convenience in accessing medical care services.
8. I think that technologies in primary care can enhance the quality of my life.

Perceived barriers of taking action
9. I am concerned that technologies in primary care are not adequately secure and that it might lead to the leak or abuse of my personal information.
10. I am concerned that technologies in primary care would violate my privacy.
11. I am concerned that the accuracy and reliability of technologies in primary care are not high enough.

External cues to action
12. I think that relatives will encourage and support me to use technologies in primary care.
13. I think that friends will encourage and support me to use technologies in primary care.
14. I think that medical care personnel will encourage and support me to use technologies in primary care.
15. Media endorses the use of technologies in primary care.

Attitude towards using
16. I think I will like using technologies in primary care.
17. Overall, I consider technologies in primary care to be just right.
18. In my old age, using technologies in primary care would be ideal.

Behavioral intention to use
19. Overall, I am highly willing to use technologies in primary care.
20. If necessary, I would use technologies in primary care often.
21. In my old age, I am willing to use technologies in primary care.
22. In my old age, I would use technologies in primary care often.

The interviews were transcribed verbatim. Afterwards, the researcher (MH) checked the transcripts against the audio recordings. Field notes from the interviews were also included in the analyses if they were available. The researcher (MH) independently coded the transcripts of the interviews using open coding. The following codes regarding technologies in primary care were used: first opinions, advantages, disadvantages and preferences.

III. RESULTS

This section provides the preliminary results of this study. First, an overview of the characteristics of the participants is given, followed by the mean scores of the subscales of the questionnaire, the spread of participants on the different subscales, the differences between groups, and participants' preferences for using specific primary care technologies. Furthermore, the main results of the structured interviews are described.

A. Characteristics of study participants

In total, sixty-three participants filled out the questionnaire. Six participants were excluded from the analyses because their age was below 50 years. The mean age of the remaining fifty-seven participants was 67 (SD: 9.26, range: 51-85). Twenty-one of them (37.5%) were male and twenty-eight (49.1%) had one or more chronic diseases (including diabetes type I and II, cardiovascular diseases, diseases of the joints, cancer, diseases of the nervous system, respiratory diseases, depression and/or anxiety disorders).

Six participants agreed to participate in an interview, of which 4 (66%) were male. The mean age of the interviewed participants was 64.4 (SD: 10.16, range: 52-76).

B. Scores subscales questionnaire

Figure 1 shows the mean scores of subscales of the questionnaire. The mean score of general technology experience was 3.42 (SD: .95), the mean score of experience with technology in healthcare was 2.22 (SD: 1.17). The mean score of perceived benefits was 3.88 (SD: .77), the mean score for perceived barriers of taking action 2.85 (SD: .93). External cues to action scored 3.56 (SD: .86). The mean scores of attitude towards using and the behavioral intention to use were respectively 3.83 (SD: .82) and 3.79 (SD: 1.00).

Figure 2 shows the spread of participants on the different subscales. It can be seen that 50% of the participants had a mean score between 3.5 and 4.25 on perceived benefits. The mean scores were lower for perceived barriers: 50% of the sample had mean scores between 2.0 and 3.67. Furthermore, 50% of the participants scored between 3.0 and 4.13 on external cues to action. In addition, half of the participants had mean scores between 3.33 and 4.67 on attitude towards using and scores between 3.0 and 4.63 on intention to use.

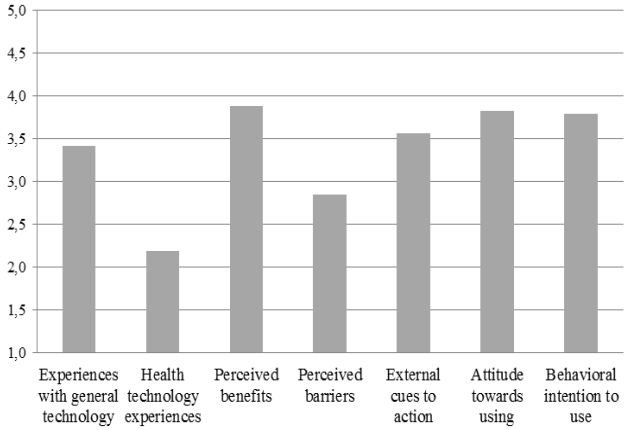

Figure 1. Mean scores of the different subscales of the questionnaire.

Looking at the differences between groups there was a significant difference (*p*: .050) between age groups on general technology experience, with a mean score of 3.66 (SD: .90) for participants with an age below 65, compared with a mean score of 3.15 (SD: .95) for participants aged 65 years or older. In addition, there were significant differences between participants with low general technology experience and high general technology experience on perceived benefits (*p*: .013), attitude towards using (*p*: .001) and intention to use technology in primary care (*p*: .001), with higher mean scores for participants with high general technology experiences (respectively 4.14, SD: .54; 4.19, SD: .70 and 4.25, SD: .67) compared with participants with low general technology experiences (respectively 3.63, SD: .86; 3.48, SD: .80 and 3.38, SD: 1.10). Furthermore, no significant differences were found between the other subgroups.

C. Preferences for specific care technologies

At the end of the questionnaire the open question "What kind of technologies would you like to use at home? And why?" was asked. The most frequently mentioned technology was an AAL motion tracking system (n: 11), followed by self-monitoring systems to monitor blood pressure, heartbeat or glucose level (n: 5), online appointments (n: 5) and online video consults (n: 5). In addition, six participants responded that they did not want to use care technologies in care at that moment, five participants mentioned that they had no idea, and twenty-three participants did not answer the question.

D. Structured interviews

In general, at the start of the interview participants had some ideas about what kinds of technologies could be used in primary care. Most participants linked these technologies with using a computer.

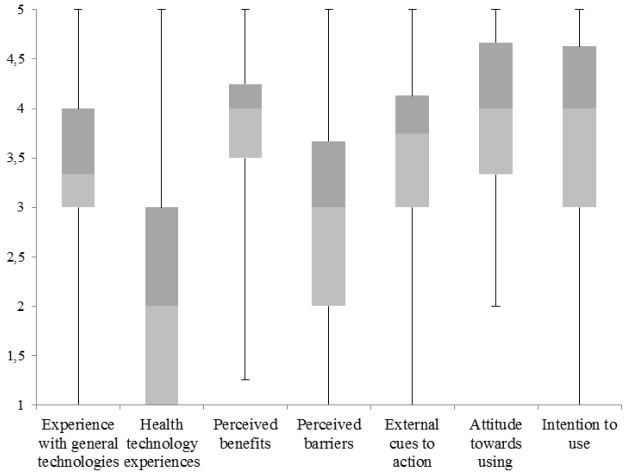

Figure 2. Spread of participants on the different subscales. The boxplots are demonstrating extremes, interquartile range (25%-50% light grey; 50%-75% dark grey) and median.

"Today, when my blood pressure needs to be measured, I first have to make an appointment with the general practitioner, and I have to take some time off. That's a hassle…" (Female, 54 years)
"*If you don't feel quite well at night, and you call the doctor, it would be good if they could give you advice on the basis of self-measured data. Then, you feel more reassured…"* (Male, 52 years)
"Nowadays, if there is something wrong I have to call my neighbors. If I can contact caregivers with just one push on a button I don't have to call them. That's a big advantage, and I can receive help quicker. (Male, 75)
"Many elderly persons have difficulties with walking. It is a great advantage if you only have to push a button to directly contact a care institution. Just with a simple connection…" (Male, 52 years)

Besides these positive responses, many participants doubted if care technologies were not too difficult in use.

"But that is just too difficult for us. It's the age, we did not grow up with technology… Reading an email is already too difficult for us…" (Male, 75)

The participants with an age over seventy linked technology immediately to difficult to use computers and mobile phones. When we showed them an Ipad, they were surprised about the small size and the user-friendly design.

"I really don't want to have a computer, I just don't want to." After showing her the Ipad:"*Is this the entire device? Is everything included? Internet as well? So this doesn't have to be connected to a wire?.... If I push on this button I can send a message? This is not difficult, for this I don't have to follow a computer course. I was thinking about a big screen…"* (Female, 76)

In addition, participants doubted if personal contact will not disappear when using primary care technologies.

"I think using technologies in primary care is positive, however, if you need care, you need human contact. Not only devices, it should be a combination between technology and personal attention…" (Female, 54)
"I hope that technology can accompany care, but that contact will always exist. That is really important…" (Male, 52)

Furthermore, some participants mentioned that getting feedback from the care giver is important.

"If I take the effort to measure my blood pressure and send the data to my general practitioner, I would like to get a message like: you're blood pressure is okay, in three months you get a new message…" (Female, 54)

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"At this moment I write my blood pressure results on a note…. However, if I take the results with me to the general practitioners or specialist, they do nothing with these data. With these new technologies, you sent a lot of data to the general practitioner, however, they should do something with it…" (Male, 65)

IV. DISCUSSION

Overall, participants had a positive attitude towards using technologies in primary care and their behavioral intention to use technology in primary care was high. These results are in line with studies investigating attitude and intentions regarding telecare and eHealth [19, 20]. In addition, scores of perceived benefits were higher than scores of perceived barriers. Participants with a high degree of general technology experiences had significantly higher scores on perceived benefits, attitude towards using and intention to use technology in primary care, than participants who had less experience with general technology use. Similar results were found in a study by Wilson et al. [21] that showed that participants who already relied on the internet in daily life, were more likely to accept eHealth.

Structured interviews revealed that time-saving, comfort and a higher degree of safety were the most expected advantages of using technologies in primary care. On the other hand, the possible lack or decrease of personal contact and usability difficulties were the most frequently expected disadvantage of using primary care technologies. Time-saving as advantage and less face-to-face contact as disadvantage were also found in previous research [22] investigating patients' expectations and experiences towards an online appointment booking system. In a study investigating the risks and benefits of home telecare [20], trust of the equipment was found to be a concern among patients. This was not found in the present study.

In a recently published eHealth monitor in which the development and progress of eHealth in the Netherlands was described [23], it was indicated that the Dutch population is still relatively unfamiliar with eHealth and the use of eHealth applications. eHealth applications that can monitor health data are not commonly used. This is in line with the low scores we found on experiences with technology in primary care.

A. Strengths and limitations

A strength of this study is that it aimed to investigate the expectations towards using care technology on a larger scale in primary care in an important 'potential user group' of this technology. By not focusing on the expectations regarding one specific technological innovation but on the broad use of telecare technologies and eHealth applications, this study provided insights that could be taken into account when implementing such technologies in primary care.

In this study a cross-sectional mixed method approach was used, combining quantitative and qualitative data. Besides questionnaires, interviews were conducted to gather more in-depth information about expectations of care technologies in primary care. These interviews were conducted with different participants than the people who filled out a questionnaire. Therefore, a cross validation of the data could not be made.

Another possible limitation of this study is that the number of currently included participants is small and therefore no generalizations can be made based on the preliminary results reported in this paper. In addition, in studies by Huang et al. [16, 17] in which the Health Belief Model was used to predict the intention to use telecare, a distinction was made between chronically ill patients [16] and general public [17]. The factors which had an influence on intention to use telecare differed between the two samples according to Huang et al. [16, 17]. In the current study no differences were found between patients with a chronic disease and patients without a chronic disease. This could also be caused by the small sample size of the present study. In addition, more than half of the participants did not respond to the question which technologies they would like to use at home or answered that they do not need it at this moment. This might be the result of the fact that these people currently do not have any complaints for which these technologies could be used.

Furthermore, the study took place in a sports hall during an event about health exercises for elderly people. Because of this event, the noise level was quite high which could have influenced the data collection process to some extent. However, the noise level did not seem to disturb the study and it created an informal atmosphere.

V. CONCLUSION AND FUTURE WORK

This paper discusses the preliminary results of this study. In the upcoming months, the data collection will be continued. Based on the preliminary results it can be concluded that middle-aged and elderly persons have a positive view towards primary care technologies.

Recently the project eLabEL [24] has started within the Centre for Care Technology Research [25]. In this three-year program 'living labs' within primary care centers will be established in which new care technologies can be implemented and evaluated in 'real life' environments on a substantial scale. Ten large primary care centers in the Netherlands will be equipped to adopt existing state of the art technologies as part of their standard care routines.

Before eHealth applications and telecare technologies can be implemented, several other factors should be further investigated. For example, privacy and security are important issues while sharing personal health related information [26]. In addition, connecting and integrating different technologies to one database will be a challenge [27]. These factors will be further explored in the eLabEL project during the next two years.

The present study provides insights in the views of Dutch middle-aged and elderly persons towards using telecare technologies and eHealth applications in primary

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care, which should be taken into account during the implementation of primary care technologies.

ACKNOWLEDGMENT

eLabEL is a project of the Center for Care Technology Research [25]. This work is partly funded by a grant from the Netherlands Foundation for Health Research and Development (ZonMw); grant number: 10-10400-98-009.

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Real-world Gyroscope-based Gait Event Detection and Gait Feature Extraction

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***Abstract*—Falls in older adults are a major clinical problem often resulting in serious injury. The costly nature of clinic-based testing for the propensity of falling and a move towards home-based care and monitoring of older adults has led to research in wearable sensing technologies for identifying fall-related parameters from activities of daily living. This paper discusses the development of two algorithms for identifying periods of walking (gait events) and extracting characteristic patterns for each gait event (gait features) with a view to identifying the propensity to fall in older adults. In this paper, we present an evaluation of the algorithms involving a small real-world dataset collected from healthy adults in an uncontrolled environment. 92.5% of gait events were extracted from lower leg gyroscope data from 5 healthy adults (total duration of 33 hours) and over 95% of the gait characteristic points were identified in this data. A user interface to aid clinicians review gait features from walking events captured over multiple days is also proposed. The work presents initial steps in the development of a platform for monitoring patients within their daily routine in uncontrolled environments to inform clinical decision-making related to falls.**

Keywords-eHealth; Falls; Gait; Wearable Sensors.

I. INTRODUCTION

The global population is ageing - the proportion of the population over 60 years of age has risen from 8% in 1950 to 11% in 2009, and is expected to dramatically increase to 22% in 2050 [1]. This trend will place an enormous burden on healthcare systems and the instantiation of a proactive, preventative approach to delivering healthcare is gaining recognition. Falls are a major problem amongst the older adult population and can lead to injury, hospitalization, restricted mobility, and institutionalization [2]. Falls in older adults have been estimated to cost in the region of U.S. $20 billion per year [3]. The instrumentation of standard clinical tests has been shown to discriminate between fallers and non-fallers [4], [5]. However, as clinic-based testing is costly and often performed infrequently, research is beginning to focus on home and community-based technologies. Such technologies would provide insight into the variability in daily activities over extended periods. This paper focuses on the development of technology which translates the assessment of gait from a clinical to a home/community based setting.

Technologies for home-based gait monitoring can be divided into two categories: non-contact technologies and wearable sensors. Non-contact technologies range from image-based techniques (e.g. the Microsoft Kinect platform [6]) to sensorised floors (such as the GaitRite [7] walkway or The ELSI Underfloor Sensing Laminate by Marimils Oy [8]). Image-based systems have the limitation of not catering well with the changing orientation and/or position of the person or the inability to capture gait data for the entire day as the person moves between different locations. Additionally image-based systems have privacy concerns. While sensorised floor systems may provide a high level of detail, often these systems are expensive to deploy and require specialist expertise to install. Motion sensor based platforms, such as Passive Infra-Red (PIR) sensors, can capture variations in transition times between locations in an unobtrusive fashion, however the gait metrics derived for such systems are generally limited to gait speed measurements and their diurnal variations [9]. Wearable technologies are generally composed of inertial sensors (including accelerometers and/or gyroscopes) applied to various locations on the body (such as the waist or on the lower shanks). Wearable sensors have been shown to derive multiple gait parameters (such as stride length) from walking events (known as gait events) through identifying the repeating gait characteristic points of the gait cycle (such as initial contact point). In many cases wearable sensors have extracted the gait characteristic points using angular velocity (captured via a gyroscope) and/or linear acceleration data, from inertial sensors (often placed on the legs) [10], [11]. To date, a number of gait feature extraction algorithms have focused upon gyroscope data which quantifies rotation in multiple axes, and is therefore less dependent on the exact positioning of the sensor [12]. Wearable inertial technologies may provide a high utility (in terms of the number of gait features they can report), however they also require the conscious participation of the user (for example in applying the sensors daily). As such the successful instantiation of wearable sensors over extended term deployments may prove challenging. In contrast, wearable inertial sensors continuously extracting gait features can monitor and quantify longitudinal variability in gait, and this may provide a greater clinical insight into why falls occur than a single clinic-based falls assessment.

Inertial sensor technologies have recently been investigated for their suitability for extended deployments in home and community settings [13]. While clinic-based data collection and analysis platforms are becoming more stable, significant

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challenges exist when moving towards the real-world [14]. For example, data collection in uncontrolled environments requires stable and extensively tested platforms requiring minimal user interaction, with the added complexity of data being transferred seamlessly to central servers. Analysis will likely be subsequently performed on the collected data with results made available for later examination by users, carers and/or clinicians. In the context of gait data, this challenge is made more difficult through the highly variable nature of real-world gait data; users may only walk for limited periods of time, those walking events may be short in duration, the environment may affect the nature of the gait cycle, and the persons own gait cycle may change throughout the day (perhaps across different environment, through tiredness, from diurnal variations and/or the effect of medications taken at different times throughout the day). Potential clinical benefits lie in bringing gait information together with contextual details, as demonstrated through associating images with gait data [13]. Furthermore, making this gait information accessible to clinicians through an interactive interface is crucial to the success of the system. This interactive tool must be easy to use, present meaningful data in a format that is easily interpretable and support the clinician in querying the data so as to inform an appropriate intervention.

This paper discusses the development of a platform which identifies gait events in continuous inertial data from wearable sensors, extracts gait features for each of these events, and presents this information to a clinician through a simple interface. A significant contribution of this work is that it pertains to the application of gait feature extraction on real-world data, and uses adaptive algorithms designed to allow for intra- and inter-individual variations. This system is evaluated using data collected from a healthy adult cohort. Future work will evaluate this system with an older adult cohort. This study design has been chosen in order to minimise any technical or user acceptance issues before involving a sensitive older adult cohort. The first algorithm analyses long duration (typically over 6 hours) gyroscope signals across 5 healthy adults, recorded in an uncontrolled environment during a routine day, to detect possible gait events. The second algorithm augments an adaptive gait feature extraction approach [11] to work on gait cycle signal shape, identifies the gait characteristic points and subsequently calculates commonly reported gait parameters. Results from an evaluation of the algorithms using data from healthy adults is presented along with a proposed user interface to feed back gait parameters for walking segments performed throughout the day to a falls specialist.

II. BACKGROUND

In a recent review, Taraldsen et al. [15] surveyed a number of papers examining physical activity in older adults, all using accelerometers, over durations longer than 24 hours. Studies were broadly divided into two areas: Activity Counts (reporting energy expenditure and/or intensity of activity) and Activity Recognition (reporting stepping or walking events, posture, and/or transitions). It was noted that in order to compare across studies there is a need for a consensus in both activity monitoring protocols and also the variables (in this case, gait features) reported. As described briefly in Section I, both the technologies and methods by which gait features are derived varies widely. The diversity in gait feature extraction algorithms is evidenced in a systematic review using inertial sensors by Yang et al. [16]. Significant effort has been undertaken to validate these gait features using clinical gold standards. However, as gait monitoring moves from a stand-alone clinical snapshot (taken no more than once per year) to multi-day home-based gait monitoring, significant technical and person-centered challenges exist including the processing of continuous gait data, feeding back the gait information to clinicians and users, and the acceptability of the gait data collection system.

In terms of moving towards data collection in uncontrolled environments using inertial sensors, gyroscope-based features of gait cycles have been identified from walking data by comparing successive steps and extracting specific gait characteristic points [11], [17], [18]. Four of these characteristic points [19] (as illustrated in Figure 1) are relatively easy to identify:

1) Mid-Swing (MS) point: highest position of the leg during the gait cycle;
2) Initial-Contact (IC) point: initial contact of the foot with the floor;
3) Full-Contact (FC) point: full contact of all the surface of the foot and the floor;
4) Terminal-Contact (TC) point: terminal contact of the foot with the floor before the next step.

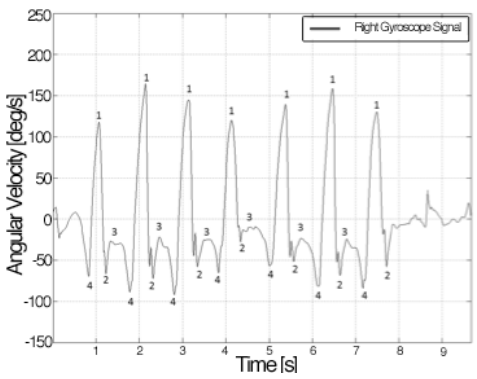

Figure 1: Example of gait gyroscope signal from the left shank over 7 gait cycles with annotated points 1) MS point; 2) IC point; 3) FC point; 4) TC point.

Over recent years, several algorithms have been described for the identification of these characteristic points [11], [20], [21]. In particular Sabatini et al [20] adopted an approach using empirically-defined signal values during experiments. However, it was found that this was too dependent on specific measurements, and not always feasible in everyday-life context across varying environments and people. Subsequently, Lee et al [21] adopted an approach focussing on finding patterns within the gait signal and demonstrated this using a quasi real-time analysis system. The system produced a high accuracy and a small delay in detection of gait events. Greene et al [11] used an adaptive approach to initially identify the MS points and to subsequently identify the remaining gait characteristic points (IC, FC, and TC). This approach allowed for varying heights in the MS point which occur both between successive gait cycles and also across different individuals. Subsequently

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local minima and maxima were determined through firstly ensuring they were of a certain range and subsequently finding the peak and trough points.

After the characteristic gait points are found, a number of gait features can then be derived. While the number of gait parameters that may be extracted from the gait cycle is large (for example, 130 variables were identified from falls risk assessments using inertial sensors [22]), often only a subset of these are commonly reported in the literature. These include:

- Cadence: number of steps per minute.
- Stride time: the time from IC of one foot to IC of the next foot.
- Coefficient of Variation (CV) of stride time: ratio of stride time standard deviation and stride time mean.
- Stride length: distance covered between the TC and IC points of the same foot.
- CV stride length: ratio of stride length standard deviation and stride length mean.
- Stride velocity: stride length divided by stride time.
- CV stride velocity: ratio of stride velocity standard deviation over stride velocity mean.

As outlined above, significant work has been undertaken in the extraction of gait features from inertial data from wearable sensors in clinic-based environments. However, limited research has taken place in catering for the additional challenges in moving towards gait assessment from uncontrolled real-world environments (such as the home and community).

III. METHODS

The gait of 5 healthy participants (3M, 2F, mean age: 30 years old) has been measured using the SHIMMER wireless sensor platform [23] placed on participants lower shanks using an elasticated bandage. All participants worked in a research environment mainly performing desk-based research and were asked to continue performing their normal daily activities. The participants were instructed to wear the sensors for as long as was comfortable. The sensors were removed at the end of the working day corresponding to a mean duration of 6.6 hours of data. Shimmer data were synchronized manually after data collection. Accelerometer and gyroscope signals were recorded at a sampling rate of 51.2 Hz and stored locally on an SD card. The gyroscope data was low-pass filtered with a cut-off frequency at 20Hz using a 5^{th} order Butterworth filter. Gyroscope signals were post-processed off-line using the MATLAB®platform [24].

IV. REAL-WORLD GAIT FEATURE EXTRACTION

Two novel algorithms are presented in this section. The first algorithm identifies periods (or frames) of inertial sensor data where a gait event has likely occurred. Subsequently, for each frame of data, a second algorithm is applied which extracts multiple gait features.

A. Identification of Gait Events

Each frame of gait data is found by identifying a recurrent signal peak corresponding to the MS point occurring over multiple gait cycles. Below, the steps of the algorithm are described in detail. Figure 2 shows multiple gait events identified from continuous gyroscope data.

Step I - LP Filter: The signals are low pass filtered with a zero-phase 5th order Butterworth filter with a 3Hz cut off frequency.

Step II - Calculate the adaptive threshold: An adaptive threshold is used to identify the MS point candidates in the left and right gyroscope signals. Firstly peaks are found using the derivative of the signal. The adaptive threshold is defined as an average of heights, in degrees/sec, of the top ten peaks and scaled by 0.2. A minimum value of 40 degrees/sec is taken.

Step III - Group MS peaks to identify gait event: All peaks above the adaptive threshold are found. Gait events are grouped together as one event as long as two MS peak points are not more than 4 seconds apart. Additionally, each gait event must last a minimum of 15 seconds. This duration has been chosen to ensure that only events where steady state walking occurs are examined.

Step IV - Ensure left and right occurrence of gait events: Identified gait events are compared between both signals and MS peaks must occur consecutively.

B. Extraction of Gait Features from Gait Events: Framing algorithm

The extraction of gait characteristic points from the gyroscope data was performed using a modified version of the approach used by Greene et al [11], as per Figure 3. Initially, an adaptive threshold, proposed by Greene et al. [11] over the entire gait event is found (step II) and used to identify MS points (step III). Subsequently, a novel technique taking advantage of the shape of the gait cycle signal, has been adopted to identify the other gait characteristic points as shown in Figure 4 (A). In order to find the IC, FC and TC points, the signal is windowed between consecutive MS points (step III). The first local minimum is defined as the IC point, subsequently a local maximum is defined as the FC point, and lastly another local minimum is defined as the TC point (step IV). Figure 4 shows an example of the gyroscope signal and characteristic points during the final phases of the algorithm.

Step I - LP Filter: A 5th order Butterworth low-pass filter with cut-off frequency 5Hz is applied to the gyroscope data to remove noise components.

Step II - Calculating the adaptive threshold: The adaptive threshold is defined as per Greene et al [11] and is calculated as:

$$th = 0.8\frac{1}{N}\sum_{i=1}^{N}(\omega_{ML_i} > \overline{\omega_{ML}}) \quad (1)$$

Where $\overline{\omega_{ML}}$ is the mean of the medio-lateral (ML) angular velocity signal and N is the number of samples occurring above the mean.

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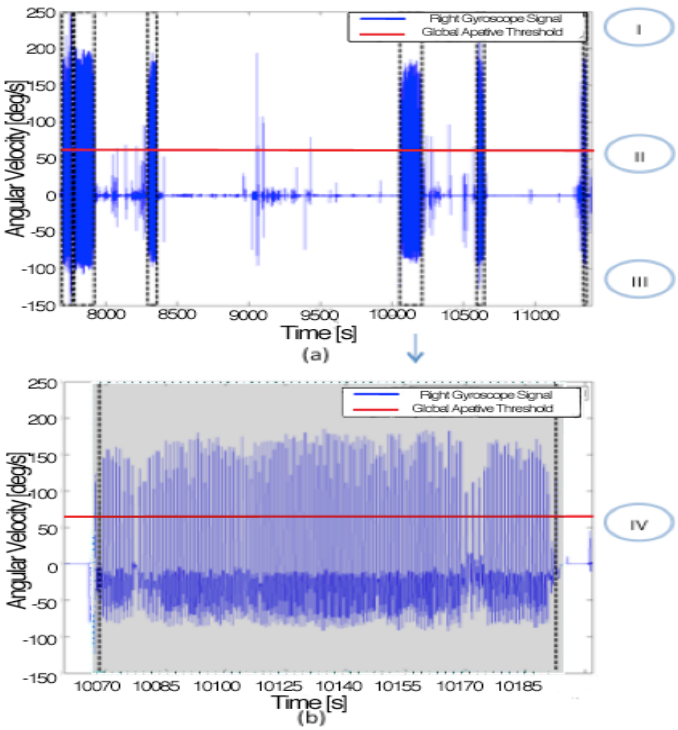

Figure 2: Example of right gyroscope signal processing through the described algorithm where the Roman Numberals in the circles refer to the steps of the algorithm. Part (a) is the gyroscope signal filtered at 3Hz. Each identified gait event is outlined by dotted rectangles. Part (b) shows the gyroscope signal for the gait event occurring between 10060 and 10210 seconds. The black dotted rectangle delineates the entire gait event identified. The shaded rectangle (slightly larger than the black dotted rectangle) shows the edges of the gait event as identified by the gait feature extraction algorithm.

Step III - Identifying the MS points: MS points are defined to occur above the threshold and the peak of the signal above the threshold are identified as candidate MS points. Candidate points occurring after 0.5 seconds are excluded.

Step IV - Frame the signal between consecutive MS points: The 5Hz filtered signal is framed between 2 MS candidates and the highest peak in the frame is selected as FC candidate.

Step V - Identify IC and TC points: The minima occurring between the first MS point and the FC point is identified as the IC point and the minima occurring between the FC point and the second MS point is identified as the TC point. This process is repeated for each frame. For each point, a window of data occurring on the 20Hz signal 0.1 seconds either side of the point is extracted and each point is updated to occur at the local minimum within this window.

Step VI - Artefact rejection: If any artefacts, identified using the following list, were found, that data was removed from the calculation of gait cycle parameters.

- If the difference between IC and TC points is greater than 2 seconds.
- If the TC point is before the IC point.
- If the TC point is before the FC point.
- If the difference between two MS points is greater than 1.75 times the mean difference within that frame.

Step VII - Calculate gait parameters: A number of gait parameters have been derived from the gait characteristic points [11], [25] including walking time, number of steps, cadence, stride time, CV stride time, stride length, CV stride length, stride velocity, and CV stride velocity.

V. RESULTS

Tables 1 and 2 report results from the analysis of the daily monitoring of the 5 healthy participants involved in the study. Data was recorded for between 5.5 to 7.9 hours long (Table 1). In particular, participants 1 and 3 (with a length record of 5.6 and 6.5 hours respectively) had the highest number of gait events (27 and 25) and walking times (1413.8 seconds and 1214.29 seconds). Participants 2 and 5 (length record respectively 7.9 and 7.4 hours) had the lowest number of gait events (15 and 7) and walking times (650.89 seconds and 566.78 seconds).

To evaluate the accuracy of the algorithm for gait event identification, a manual analysis of signals was performed, thus providing a gold standard for evaluation. The algorithm correctly identified 92.5% of all gait events. Such a high accuracy is due of the adopted adaptive techniques that allow the algorithm to correctly analyse signals in different gait situations (e.g. different speed or walking time). Table 1 shows also that globally the minimum walking time was about 20 seconds (when walking periods less than 15 seconds were excluded) for all participants (except for participant 5 with 26.58 seconds), while the maximum registered walking time was longer, for example participants 5 (197.10 seconds), 1 (178.50 seconds) and 3 (154.90 seconds) and shorter for participants 2 and 4 (81.31 seconds and 90.88 seconds).

All gait derived parameters in Table 2 have been calculated taking advantage of the identified characteristic points through the Framing algorithm. The mean cadence was between 99.62 and 110.85 steps/min for participants 1,2,3 and 4. Participant 5 had the highest cadence with a value of 129.07 steps/min. Concerning the mean stride time, participant 3 had the highest average value (1.18 seconds) while the other participants were all around 1.10 seconds. The mean stride length was higher for participants 1 and 3 (1.20 and 1.21 metres), while participants 2 and 4 had the lowest values (1.01 and 1.02 metres). Finally, the mean stride velocity was around 1.10 m/s for all participants except participant 4 who had a value of 0.97 m/s. Concerning the coefficient of variations, the values were around 0.10% for the mean CV stride time and 0.5 for mean CV stride length and velocity.

Gait information produced by these algorithms can be overwhelming and difficult for clinicians to interpret due to the number of metrics reported, and their decontextualised nature. A prototype user interface is proposed in Figure 5 to allow clinicians user friendly access to information concerning daily gait patterns. Such an interface allows the clinician to inter-rogate gait data as required. General information concerning the selected day (walking time per day and total activity per

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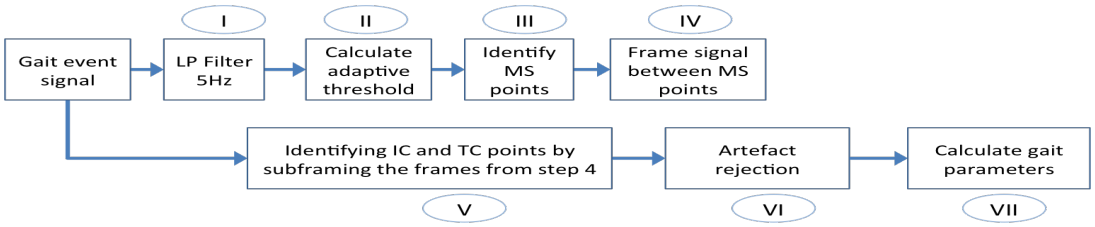

Figure 3: Framing algorithm.

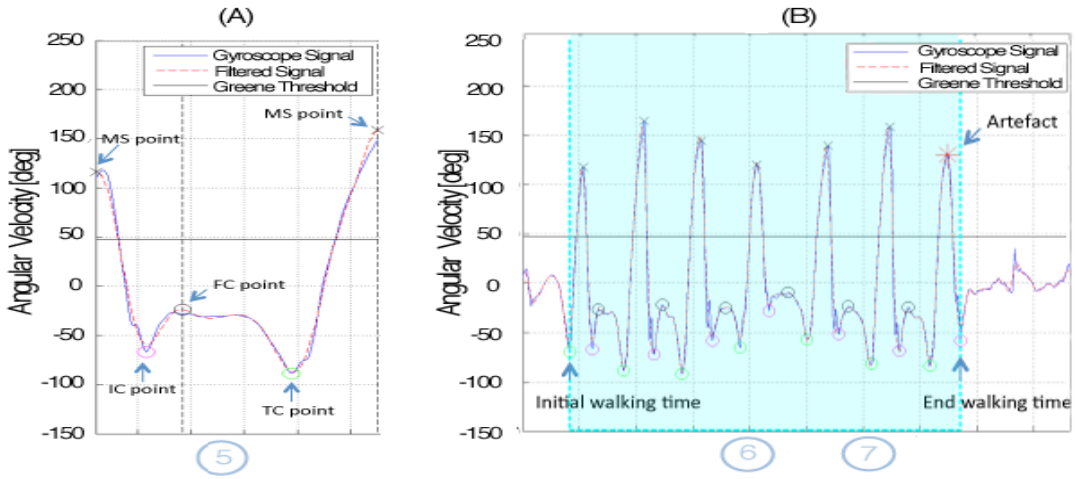

Figure 4: Example gyroscope signal for one gait event (A) and a number of consecutive gait events (B). In (A), a single gait event, between MS points, is shown along with IC, FC and TC points. In (B), the gait event under analysis (highlighted with a transparent blue shading) is shown along with an artefact (identified as no future IC, FC or TC points are found). The numbers in circles refer to steps in the Framing algorithm from Figure 3.

TABLE I: Results from the gait experiments.

Subject ID	Total record time [hours]	# of identified gait events	correctly identified events (number of missed)	Total walking time [s]	Min walking time [s]	Max walking time [s]	Min # of steps	Max # of steps
1	5.6	27	90 % (3)	1413.8	19.38	178.5	31	352
2	7.9	15	88.2% (2)	650.89	19.75	81.31	29	161
3	6.5	25	89.2% (3)	1214.29	19.67	154.9	33	253
4	5.8	19	95%(1)	679.06	18.55	90.88	25	171
5	7.4	7	100%	566.78	26.58	197.1	54	425

hour) or the previous week (activity over previous week) is presented on the upper panel. The middle panel provides the ability to select gait events which occurred throughout the day in order to provide gait information for that event. The calculated features for the selected gait event (as shown on the bottom right) and the corresponding gyroscope signal (bottom left) is also presented.

VI. Conclusions

This paper presents a platform that extracts gait information from gyroscope sensors placed on the lower shanks. The system automatically identifies gait events, extracts gait characteristic points for each event, and subsequently derives gait features. The identification algorithm accurately detected 92.5% of gait events from a day of gait data from 5 healthy adults (total duration of 33 hours). Upon a visual examination, the Framing algorithm successfully identified over 95% of the gait characteristic points using gyroscope data from the successive gait cycles within the gait events. A validation study using a larger and more varied cohort is required to evaluate the accuracy of the Framing algorithm. Further experiments with older people (mean age >60 yrs) will be beneficial for the project as studies reveal that one in three adults aged 65 and older fall each year. However this validation will be difficult as traditional approaches have been clinic-based, and this may not translate well for uncontrolled home and community environments. For example, the context of where the person is walking may be very important (e.g. is the surface uneven?) or other factors which may affect the biomechanics of walking (e.g. what type of shoes are being worn?). Additionally, longitudinal changes in gait may be more important, and as such technologies which provide a broad insight may be clinically useful (e.g. how has gait speed changed over the past year?).

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TABLE II: Derived parameters from the analysis.

Sub ID	Cadence (num steps per min)	Mean stride time [s]	Mean CV stride time [%]	Mean stride length [m]	Mean CV stride length [%]	Mean stride velocity [m per s]	Mean CV stride velocity [%]
1	104.43 ±12.43	1.14 ± 0.12	0.12 ± 0.06	1.20 ± 0.09	0.48 ± 0.07	1.09 ± 0.11	0.52 ± 0.12
2	104.92± 15.27	1.08 ± 0.14	0.11 ± 0.05	1.01 ± 0.07	0.49 ± 0.05	0.97 ± 0.13	0.51 ± 0.06
3	99.62 ± 7.06	1.18 ± 0.06	0.10 ± 0.04	1.21 ± 0.08	0.48 ± 0.05	1.04 ± 0.09	0.49 ± 0.05
4	110.85 ± 13.67	1.04 ± 0.19	0.12 ± 0.08	1.12 ± 0.09	0.48 ± 0.08	1.12 ± 0.15	0.50 ± 0.08
5	129.07 ± 13.22	1.10 ± 0.04	0.11 ± 0.03	1.02 ± 0.05	0.51 ± 0.04	1.12 ± 0.04	0.52 ± 0.04

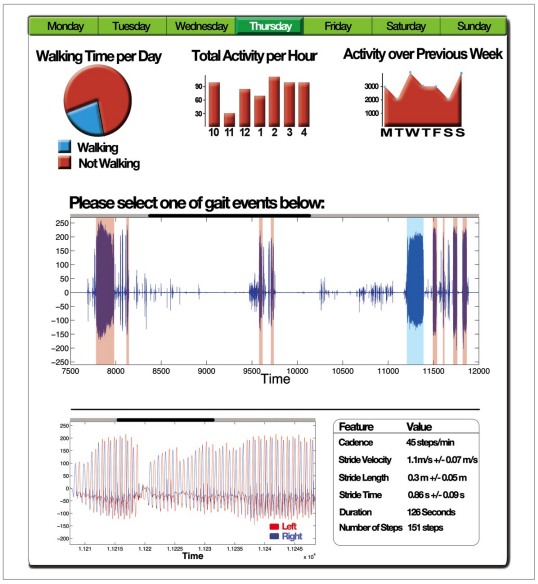

Figure 5: Clinician user interface for gait data

While the platform presented in this paper is applied to data from healthy adults, on-going work is investigating applying the methods to data collected in an older adult population where it can be reviewed (post data collection) by a clinical falls specialist. This system aims to present more contextualized gait information, collected in home and community settings, to support clinical decision making and inform falls interventions, as necessary. Significant challenges exist in the further development of this system including extracting gait features from individuals with an impaired gait.

We further plan to implement the proposed user interface in a web-based system (accessible via secure connection through laptop, tablet or smartphone) which could be accessed by both physicians and patients with the aim of leading to better self-management of the older population.

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Developing a Supportive Tool to Facilitate Shared Decision Making in Dementia

Involvement of end users in the design phase

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Abstract— **Developing an IT application facilitating Shared Decision Making (SDM) in dementia is complex. This is caused by the increasing cognitive decline associated with dementia and the number of involved people (people with dementia, informal caregivers and case managers). The aim of this study is to identify design issues in developing a user-friendly IT application facilitating Shared decision-making in dementia. Data collection in this study with an iterative participatory design based on the CeHRes roadmap included: focus group interviews with people with dementia, informal caregivers and case managers; a cognitive walkthrough with researchers; and a first usability test with case managers. This resulted in a list of issues addressing the quality of the system, content and service and a revision of the tool before informal caregivers and people with dementia will be invited to participate in usability tests.**

Keywords-shared decision-making, dementia, supportive device, design, co-creation

I. INTRODUCTION

Dementia is a degenerative disease that increasingly affects people worldwide; from 66 million in 2030 to 115 million in 2050 [1, 2]. Decreasing abilities address memory loss, oute planning, behavioral change and orientation problems among other things. People with dementia and their informal caregivers are faced with many problems and decisions addressing both care and well-being [3, 4]. Unfortunately, participation of people with dementia in decision-making processes is not self-evident [5].

Shared Decision Making (SDM) is an approach that involves patients in making medical decisions in collaboration with professionals. [6, 7]. SDM increases patient autonomy and empowers the patient [5]. Several decision aids (digital or paper based) have been developed to facilitate SDM in medical decisions in the clinical setting. Our research program aims to develop an IT application to facilitate case managers in supporting SDM in care networks of people with dementia in a community setting.

This IT application distinguishes itself from existing IT applications in aiming to do justice to all involved parties, both in decision-making and in its design and development. With regard to SDM, the new IT application differs from existing decision aids. First, people with dementia and their caregivers have to make many decisions over time versus single –issue decisions. Second, the new IT application has to take into account the (decreasing) cognitive capacities of people with dementia versus decision aids that focus on cognitive able people. Third, SDM in dementia is characterized by a variety of involved persons, a network, versus regular decision aids focusing on patient-clinician relation. Fourth, decisions people with dementia and their informal caregivers have to make concern mainly care and well-being aspects, versus medical decisions in traditional decision aids.

The new IT application aims to increase the influence of people with dementia in decision-making by giving them a voice in the decision-making process of care and well-being related issues.

This paper is organized as follows. Section II elaborates on the complexity of designing an IT application in dementia networks. Section III describes the design and methods used. Section IV presents the main results: design issues. Finally, Section V provides a conclusion and future work.

II. BACKGROUND

Developing an IT application facilitating SDM in dementia is complex because it involves a variety of people (people with dementia, informal caregivers and case managers) with different capacities and different interests and the cognitive decline inherent to dementia. Computer interfaces do not fit all persons. Older persons and disabled persons, e.g., persons with dementia are not average web users. They have problems using a ‘one size fits all’ computer interface [8]. Zaphiris et al. [9] distinguished guidelines when designing computer interfaces for older people in their review (e.g., information should be concentrated mainly in the center; clear navigation should

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be provided; screen layout should be simple, clear and consistent; colored text on colored background should be avoided). Savitch and Zaphiris [10] noticed that the terminology and phrases used when designing for people with dementia are extremely important – possibly more so than for the average web user. Several researchers give dementia related interface recommendations to designers: facilitating an easy orientation [11, 12]; using cues that are familiar; legible and distinctive [13]; using touch screens, large format screen and large font sizes, minimal use of text; use of a hypermedia structure with limited options for selection, and an attractive design [14]; using tablets [15]. Less information is available addressing design of interactive IT applications for users with different capacities. Nevertheless, involvement of end users is mentioned as an important feature [16]. Moreover, involvement of people with dementia leads to better attuned IT applications [17].

The present study, developing an IT application facilitating SDM in dementia, is part of a major research program on SDM in care networks of people with dementia aiming to improve professional care. Besides, developing theory building and competencies for case managers, developing a supportive IT application to facilitate SDM in dementia care networks aiming to contribute to dementia care practice. In a prior study we identified user requirements to determine the content of such an IT application [18]. This paper focuses on designing the computer interface that has to take these user requirements into account. The aim of this study is to identify design issues. The research question read: which design issues can be identified in developing an IT application facilitating SDM in dementia.

III. APPROACH

In this study with an iterative participatory design we consider involvement of end users, particularly people with dementia [17], as one of the key factors for developing a user-friendly and usable IT application.

We used the CeHRes (Center for eHealth Research and Disease Management) roadmap for the development of the IT application, because this approach connects a Human Centered Design with eHealth Business Modeling and emphasizes the importance of involving all stakeholders to develop sustainable innovations [19]. The CeHRes roadmap offers a holistic framework consisting of five phases: contextual inquiry phase; value specification phase; design phase; operationalization; and summative evaluation. This paper describes the third phase, the design of the IT application facilitating SDM in dementia.

A. Focusgroup interviews

First, eight focus group interviews were organized with end users including people with dementia, informal caregivers and case managers. The goal of these focus group interviews was to receive feedback on the first mock-ups of the IT application, the DEcideguide (Figure 1). The mock-up, including 11 slides, was presented in the focus groups [19]. End users were asked to comment on the different slides in common, textual, in content, on user -friendliness and on the (attractiveness of) design.

Twenty-seven end users participated in the six focus group interviews. The two focus group interviews with people with dementia and informal caregivers consisted both of six and four participants respectively. The focus group interviews with case managers consisted both times of the same seven participants. Participants of the second focus groups commented both on the mock-up and the feedback of the first focus group. The principal researcher, assisted by another researcher or designer, moderated the focus groups.

People with mild to moderate dementia were recruited from two day-care centers. Informal caregivers were recruited from residential homes and the Dutch Alzheimer Association. Case managers were recruited from regional case managers' networks. All participants gave their written informed consent. The focus group interviews that lasted 1-2 hours were audio taped and transcribed verbatim.

Framework analysis was used to analyze the focus group interview transcriptions [20]. The three levels of assessing design quality of the CeHRes was used as framework to identify design issues: system quality (technology that is user-friendly and safe), content quality (content that is understandable and meaningful) and service quality (service that is timely and persuasive) [21].

Figure 1. Concept SDM application. Perspective of people with dementia used in focus groups

B. Cognitive walkthrough

Second, a cognitive walkthrough session with researchers was organized to test the first interactive prototype of the DEcideguide (Figure 2). During a two hours session three researchers tested the DEcideguide using a case with the perspectives of a person with dementia, an informal caregiver and a case manager to identify bugs, possible user problems and testing the user friendliness. The session was audio and video taped. The analysis of the

transcripts focused on identifying (additional) design issues to the focus group interviews related to system, content and service quality.

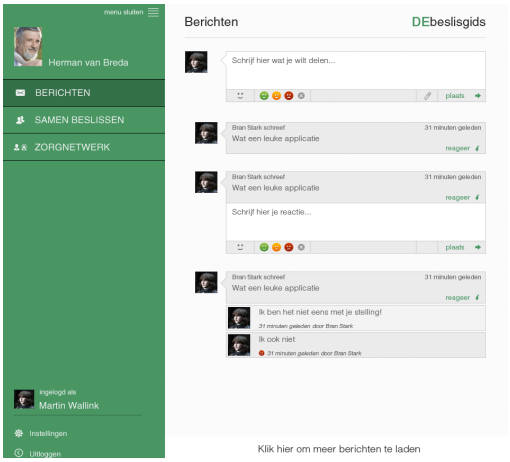

Figure 2. Chat in the DEcideguide used in cognitive walkthrough and usability test

C. Usability tests

Third, usability tests were performed with the adapted interactive prototype of the DEcideguide (Figure 2). The goal of these usability tests is to further refine the DEcideguide into a prototype that is robust enough to be used in a pilot study [22]. Case managers tested the working prototype in a two hour Think aloud session [20]. The session was audio and video taped and transcribed verbatim. The analysis of the transcript focused on identifying additional design issues. After adjusting the DEcideguide, usability tests will be conducted with elderly, informal caregivers and people with dementia in succession. We chose for this iteration in participants to iron out major bugs in an early stage in order to enable end users to focus on the refinement of the DEcideguide.

IV. RESULTS

A. Focus group interviews

All respondents participated because they experience decision-making in dementia as an important and difficult area. They expect a supportive tool to be very useful and helpful. The design issues that arose from feedback of respondents could be assigned to the three levels of design quality: system; content and service quality. Design issues addressed mainly the system quality and the content quality. Case managers were the only respondents who commented directly on the service quality. They considered the tool as very nice and useful for their practice. All respondents commented on the content quality and agreed about the difficulty of the content: too much and too difficult. Moreover, case managers' comments on the content of the tool focused on extra options they would like: e.g., skype, agenda, domotics, and separate communication with family members. Informal caregivers commented in particular on terminology. Similar questions were removed and synonym, more familiar, words given (e.g., 'social contacts' changed into 'family and friends'). People with dementia advised simplifying the tool in words and size. Most feedback addressed the system quality. Main comment of all participants focused on the 'ease of use' that was failing (Table 1).

TABLE 1 DESIGN ISSUES IN DEVELOPING THE DECIDEGUIDE

Design quality	Identified design issues
System quality	
User-friendliness	*'Nice to haves'* -Adding things like an agenda; personalized part in tool for case managers; linking with domotics; skype function -Alerts for daily activities (taking medication; eating etc) *Navigation structure/ease of use* -Too much screens for people with dementia (cm/ pwd)[a] -Simplifying the screens for people with dementia (pwd) -Too many examples with too many colors with too small letters (not all pwd agreed) -messy screens with too much information (ic) -Messages in timeline with chat become a big mess (cm) *Presentation of content* -use of smileys is clear but not really nice (pwd) -use of colors red, orange and green is nice. Use of smileys is a bit childlike (if) -frequency of monitor question differs per network. Monitoring well-being is important (ic). -Attention for use of red color in tool. Red smiley is similar to feeling not well. Using also red color for a (neutral) theme suggests 'danger' (ic) - use of colors in messages is not clear/distinguishing enough (cm+ic)
Design persuasiveness	*Lens for design* All network members view all messages because the starting point of the tool is transparency and open communication. This is not always advisable for person with dementia. (cm)
Content quality	
Comprehen-sibility	*Comprehensibility/Terminology=semantic shortcomings* -Use of some terms is not clear enough and tool difficult; e.g., options and pros and cons of options (pwd) -Use of terms is not specific enough; e.g., 'How are you right now?' instead of 'How are you today?' (pwd) *Accuracy* - Date and year are incorrect (pwd+ic) *Relevance* - Open questions are less attractive than question that also offer examples. - tool is too directive (pwd) - tool is directive: easy to use because you don't have to invent answers by yourself (ic) -adding a wish button… (ic)
Service quality	
Perceived usefulness	- the tool is very useful in facilitating SDM in dementia but how useful will it be for people with dementia? (cm)

[a]Pwd=person with dementia; ic=informal caregiver; cm= case manager

B. Cognitive walkthrough

The cognitive walkthrough with the research team resulted in a fundamental discussion that addressed the complexity of the context of decision-making in dementia. Researchers commented mainly on the complexity of the DEcideguide in particularly for people with dementia. Researchers argued that the desirable starting point of the DEcideguide, transparency between all network members, easily conflicted with the well-being of people with dementia. Researchers advised to simplify the DEcideguide for those end users.

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C. Usability tests

The feedback of case managers addressed mainly the system quality. A variety of bugs was detected together with lack of user-friendliness and presence of too many technical errors. Case managers commented also on service quality. They experienced the tool as very useful and helpful to their daily practice but in the mean time they doubted whether the tool would be useful for the current group of people with dementia because of the lack of computer experience of that group. In their opinion the transparency in the DEcideguide can be confronting and therefore conflicting with the well-being of people with dementia. Many people with dementia are suspicious. On the one hand, transparency helps to decrease suspicion. On the other hand, transparency can give an overload of information that people with dementia cannot cope with and could result in restlessness. The comments of the case managers resulted in a revision of the DEcideguide. After this revision is finished other end users will test the DEcideguide (Table 1).

V. CONCLUSION AND FURTHER WORK

The design phase of the DEcideguide resulted in a list of design issues addressing mainly user friendliness and comprehensibility. Both researchers and case managers considered that the starting points of the DEcideguide, transparency and open communication, probably conflict with the overall well-being of people with dementia because it provides too much information. The usability tests with informal caregivers and people with dementia will show whether this dilemma will be confirmed or not. Developing an IT application for various end users with different capacities and interests requires involvement of all end users in the design phase of the development trajectory.

The next step, after finishing the usability tests, is conducting a pre-pilot with the refined tool with a dementia network consisting of a person with dementia, informal caregivers and a case manager acting in daily life. Then, a five-month pilot study will be conducted and evaluated.

ACKNOWLEDGMENT

The Dutch Foundation Innovation Alliance (SIA RAAK [Regional Attention and Knowledge Circulation] PRO), Zorgpalet Hoogeveen (Residential care organization for older adults) and Windesheim University of Applied Sciences funded this study.

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Preliminary Cost-Benefit Analysis of a Real-Time Telemedicine System

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***Abstract*—Information and communication technology in the medical field has witnessed great advances at research level but it is still largely unapplied in routine clinical practice. Technology-driven solutions, proved experimentally effective, are not always efficient in the complex health world. Each form of innovation needs to be sustainable, from an economic and organizational points of view, if it is to progress from the prototype phase to become a practical element of the healthcare system. A cost-benefit analysis can help establish if this is the case. Here, we apply a preliminary cost-benefit analysis to the real-time telemedicine platform we developed. It has proven successful from a diagnostic point of view, but how does it perform from an economic perspective? Our analysis compares the overall cost of the platform to the economic savings made from its operational use - where unnecessary patients' transfers are avoided. We estimate potential savings of about 66% of current costs.**

Keywords-real-time telemedicine; pediatric cardiology; cost-benefit analysis

I. INTRODUCTION

Tele-health, when supported by solid economic and organizational design, can promote new care models (like hub-and-spoke distribution or home monitoring), fostering a rational and effective use of investments [1] [2] [3] [4]. Standard telemedicine technology proves its validity in several contexts, but is generally unsuitable to situations involving operator-dependent diagnostic techniques – it is not sufficient simply to store and send images, it also needs the timely application of specific expertise in order to complete the examination. Only by providing real-time collaboration do the standard telemedicine technologies produce value. Pediatric Cardiology is one of those clinical discipline [5] requiring a specialized operator to obtain a reliable result: echocardiography is the focus of a congenital heart disease (CHD) evaluation, and it is only accurate when performed by an expert. In general, specialists in this fields are rare and their lack is particularly critical in some regions with high incidence of this kind of disease, like Sardinia - one of Italy's major islands (Fig. 1): in Sardinia CHD has a mean incidence of 20.25%, more than twice the typical incidence [6] and there is a unique specialized center (Pediatric Cardiology Structure in *Azienda Ospedaliera* "G. Brotzu", Cagliari [7]). As can be seen in TABLE I, the distances between the center and the eight main health districts (ASL-*Azienda Sanitaria Locale*), corresponding to the main cities (Sassari, Nuoro, Oristano, Lanusei, Carbonia, Olbia, Sanluri, Cagliari), are not extreme but the logistic infrastructure can cause critical travel time for patients' life. To mitigate the high risks deriving from this situation, CRS4 [8] and Brotzu hospital carried out a research project resulting in a real-time low cost telemedicine platform, able to support clinicians with the tele-presence of a specialist in real-time during echocardiographic evaluations [9]. The platform developed allows echocardiographic exams to be performed remotely, without physical interaction between the patient and the specialist. The ultrasound analysis is operated by a third doctor who physically visits the patient, while the specialist guides the operator directly, viewing the echographic output and the examination scene at the same time. The system has proven its diagnostic value [10] and the analysis presented below is a preliminary evaluation of its economic advantages, in anticipation of a regional scale trial.

Here, we test the hypothesis that the use of our real-time telemedicine platform is economically beneficial for both the Sardinian health service and patients by comparing the system's cost to that of savings to be made in patient transport - a very specific but substantial aspect. At this preliminary stage, we do not attempt an assessment in terms of quality of care – the necessary data are not yet available. Similarly, at this stage, a cost-utility or cost-effectiveness analysis, as recommended by literature [11][12][13], is not attempted. Nevertheless, this preliminary cost-benefit study gives some indicators for the future implementation of the system in real clinical life. The *Material and Methods* section describes the system workflow and the approach for cost evaluation analysis, which lead to the estimate summarized in the *Results* section and discussed in the *Discussion* and *Conclusions*.

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Figure 1 – ***Sardinian Health District locations.***

TABLE I. DISTANCES

Distance of each Health Districts from the main hospital		
Health District (ASL)	***Distance (km)***	***Time (hours)***
ASL 1 - Sassari	216	02:19
ASL 2 - Olbia	276	02:57
ASL 3 – Nuoro	207	02:18
ASL 4 – Lanusei	125	01:52
ASL 5 - Oristano	96.9	01:08
ASL 6 – Sanluri	47.9	00:39
ASL 7 – Carbonia	71	00:56
ASL 8 – Cagliari	4.8	00:11
AO – Cagliari	4.8	00:11

II. MATERIAL AND METHODS

To evaluate the cost-benefit of our telemedicine system, we consider the route from the unique centre of specialization in Cagliari to nine secondary hospitals - one per Sardinian health district (ASL), plus another hospital in Cagliari (AO). Below we outline the method of evaluation.

A. Cost-benefit analysis: approach

We take a societal perspective, highlighting cost and benefits deriving from the use of the system both for health system and for patients – but only in terms of travel savings, since our system is not currently operational so we are yet to measure benefits in terms of effectiveness. The analysis is based on a cost comparison during the year 2012 considered with and without the system.

Currently, patients suspected of CHD are sent to Cagliari (Brotzu Hospital), by their General Practitioner (GP) or, in emergencies, sent directly by other hospitals, often by ambulance. A specialized visit then occurs to confirm CHD, or not. Visits that do not confirm CHD are indicated as unnecessary below. TABLE II details the consultations claimed by health structures or by GP (for outpatients). We enumerate the former category into both necessary and unnecessary visits – but lack the data to do the same for outpatients consultations.

With the presence of the telemedicine system, the main costs are those related exclusively to the system set-up and maintenance, while the main economic benefits consist in the savings due to avoiding patient transfers to Cagliari: the patients could be first visited in their health district and then only urgent cases sent to the main center. Therefore, the economic benefits are:

- for the patient, in saving the cost of all transfers required for outpatient consultations;
- for the health structures, in saving the cost of transfers at first considered to be urgent but revealed as unnecessary.

These costs may be evaluated by this equation:

$$C = Cv + Ct = \left[\left(\frac{Cf}{Mf} + Cu\right) * D\right] + T * \sum_{n} Mn \quad (1)$$

where:

Cv = vehicle cost (ambulance, or standard car)
Ct = team cost (only in case of ambulance)
Cf = fuel cost
Mf = medium fuel usage
Cu = fixed cost of usage
D = distance
T = time
Mn= nth member of ambulance team

When transfer is by ambulance, both the terms Cv and Ct are present, since both vehicle and the team have associated costs - which vary according to the specific conditions.

D and T are the values of distance and time, respectively, taken from TABLE I.

The term Cf is calculated as the average fuel (diesel and gasoline) costs in Italy in 2012, published by Italian Economic Development Ministry [15][16].

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TABLE II. 2012 CONSULTATIONS

Face-to-face Consultations Performed in 2012		
Health District (ASL)	***Consultations by Health Structures Required (Necessary)***	***Outpatient Consultations***
ASL 1 - Sassari	1 (1)	82
ASL 2 - Olbia	0 (0)	71
ASL 3 – Nuoro	4 (2)	164
ASL 4 – Lanusei	0 (0)	41
ASL 5 - Oristano	1 (1)	210
ASL 6 – Sanluri	2 (0)	378
ASL 7 – Carbonia	23 (5)	348
ASL 8 - Cagliari	57 (4)	1839
AO - Cagliari	18 (5)	-

B. The Platform: Description and cost evaluation

A suspected CHD case may be detected either by a GP or a health structure: with our telemedicine system in use, the patient is to be sent to the closest secondary center with a teleconsultation station. The workflow has three main parts, depicted in Fig. 2:

1. **scheduling**: the secondary center, according to the tertiary/specialist center availability, requires the teleconsultation (step 1 and 2 in Fig.2);
2. **teleconsultation**: the specialist accepts the request and starts the remote visit, interacting in real-time with the operator at the secondary center (step 3 and 4 in Fig.2);
3. **reporting**: the specialist saves the digital diagnosis in a structured report which becomes immediately available to the doctor who performed the test and to the patient (step 5 in Fig.2).

From the software point of view, the system is open-source and composed of a portable application for the sonographer, a desktop application for the specialist and a web application for managing scheduling and patient information (clinical data and reports). As for hardware, the platform requires a central server, a laptop for the specialist and, for each center requiring teleconsultation, a network camera (to record the examination scene), an encoder (directly connected to the echograph) and a mobile device like an Apple *iPod* touch (to enable the communication between the clinicians through a VOIP audio chat). So, from the hardware point of view, the system costs are the sum of these items.

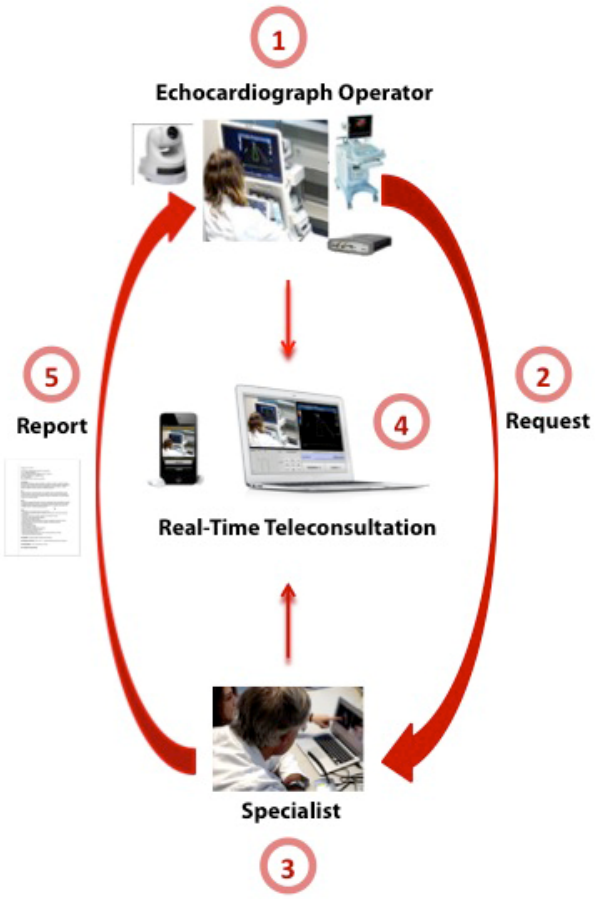

Figure 2 – ***System basic workflow.***

The costs are based on market prices: the estimate for the server is based on the idea of using a clustered virtual machine [14]. There are no additional costs for the network infrastructure: the system is designed to take advantage of preexisting networks and it doesn't need dedicated connections, requiring only 2.5MBps bandwidth. Each center has its own existing general purpose communication infrastructure so no additional costs are incurred during the development of the telemedicine intervention system due to such communication.

Moreover, each center has an IT department and the maintenance of the system can be easily incorporated in the routine maintenance of the other systems already running in each center. The platform does not require specific knowledge to be used by the clinicians once they have had a few hours training experience. TABLE III summarizes the costs for the telemedicine system.

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TABLE III. PLATFORM COSTS

Platform costs		
Type of unit	***Component***	***Price (€)***
Center Requiring Consultation	Encoder video Axis Q7401	400
	Apple iPod touch	250
	Network Camera Axis PTZ 214	1300
TOTAL FOR THE UNIT		**1950**
Center Offering Consultation	McBookAir	1000
	Central server	2000
TOTAL FOR THE UNIT		**3000**

C. Transfer costs analysis: healthcare system perspective

Adopting our telemedicine system ought to enable the specialist in Cagliari to see the patient nearer the onset of suspected CHD, allowing the patient to be transferred for therapy at an earlier stage.

It is hard to quantify a priori the advantage of such prompt intervention, but we can evaluate the savings in transfer cost. We have no hard data whether transport cost are incurred by health service (ambulance transfer) or by patient (own car) so we consider the costs in each case, supposing either transfer via ambulance or via a "standard" car. As the costs for medical and private vehicle transfer are not directly available, we estimate them using equation (1), taking into account both the cost of the vehicle and the cost of the team.

For the evaluation of the medical vehicle costs we consider a series of 10 vehicles on the market [18], obtaining for each of them an estimate of our term Cu [17] and term Mf.

For the evaluation of the team costs, we consider five kinds of team, composed by:

- A1 – driver and nurse on duty;
- A2 - driver and nurse on call;
- B1 – driver, nurse and doctor on duty;
- B2 - driver, nurse on call and doctor on duty;
- B2 - driver, nurse on duty and doctor on call;
- B3 - driver, nurse on call and doctor on call.

The hourly costs for the personnel are in TABLE IV.

TABLE IV. AMBULANCE TEAM COSTS

Ambulance team costs (€/hour)	
Team Member	***Cost***
Driver	14.80
Nurse (on duty)	16.38
Nurse (on call)	27.00
Doctor (on duty)	36.34
Doctor (on call)	60.00

Combining all these factors with data from 2012 about transfers from health structures (TABLE II), it is possible to evaluate the total costs for (necessary/unnecessary) transfer by ambulance. The methodology used to evaluate term Cv in case of private cars is described in the next section.

D. Transfer costs analysis: patient perspective

In case of non-urgent suspected CHD, patient families use their own car for all outpatient consultations. To evaluate these costs, we considered only the term Cv in (1), calculating it for a "standard" car, i.e. the best-selling car in Italy in 2012 [19], FIAT Panda "1.3 MJT 16V 95 CV". Term Mf was obtained from the manufacturer website, term Cu from ACI databases [17] and term D from TABLE I. After estimating the cost for car, we multiplied it by the number of transfers in TABLE II. We did not include transfers from within the Cagliari District since patients would already be in the hospital of destination (Brotzu Hospital) so there was no need to move.

III. RESULTS

A. Transfer costs analysis results: healthcare system perspective

The estimate of the transfer costs to Brotzu Hospital for the consultations required by other structures are presented in TABLE V, for both vehicle-types: ambulance and private car. Since for consultations by health structures we have the data for whether a request was necessary or not we also list the unnecessary costs in the table.

B. Transfer costs analysis results: patient perspective

The costs for patient transfers to Cagliari center related to outpatient consultations are depicted in TABLE VI.

C. Transfer costs analysis results: societal perspective

Considering all the results for the transfer costs analysis from health system and patients perspective, we obtained the overall cost-benefit results of TABLE VII.

In the table, the column "expenditure nature" clarifies if, for society, the amount must be considered a cost or a benefit. The costs for transfers from other structures by ambulance are marked with (A), while the costs by private cars are marked with (C).

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TABLE V. 2012 TRANSFER COSTS RELATED TO CONSULTATIONS REQUIRED BY HEALTH STRUCTURES (AMBULANCE AND PRIVATE CAR)

Costs for Consultations Required By Health Structures (Ambulance)			
Health District (ASL)	***Consultations Required (of which Necessary)***	***Ambulance Costs Due to Unnecessary Consultations Costs €***	***Private Car Costs Due to Unnecessary Consultations Costs €***
ASL 1 - Sassari	1 (1)	0	0
ASL 2 - Olbia	0	0	0
ASL 3 – Nuoro	4 (2)	572	190
ASL 4 – Lanusei	0	0	0
ASL 5 - Oristano	1 (1)	0	0
ASL 6 – Sanluri	2 (0)	149	86
ASL 7 – Carbonia	23 (5)	2481	602
ASL 8 - Cagliari	57 (4)	824	876
AO - Cagliari	18 (5)	202	319
TOTAL	**106 (18)**	**4228**	**208**

TABLE VI. 2012 TRANSFER COSTS RELATED TO OUTPATIENT CONSULTATIONS

Consultations required by GPs		
Health District (ASL)	***Consultations Required***	***Consultations Costs €***
ASL 1 - Sassari	82	6113
ASL 2 - Olbia	71	6763
ASL 3 – Nuoro	164	11717
ASL 4 – Lanusei	41	1769
ASL 5 - Oristano	210	7023
ASL 6 – Sanluri	378	6249
ASL 7 – Carbonia	348	8527
ASL 8 - Cagliari	~~1839~~	NOT CONSIDERED
TOTAL	**1294**	**48163**

The cost-benefit analyses are summarized in TABLE VIII, which shows that our telemedicine platform could help save between 33586 € and 35740 € within one year, reducing the costs of the system to 66% of the total expenditure. Moreover, in the future hardware costs should decrease, while the same is not expected for transport costs.

TABLE VII. COMPARISON OF 2012 COSTS WITH AND WITHOUT THE TELEMEDICINE SYSTEM

Comparison Of Costs With And Without The Telemedicine System			
Expenditure Cause	***Expenditure Type***	***Costs With Telemedicine €***	***Costs Without Telemedicine €***
Regional Telemedicine System	Cost	16650	0
Necessary Transport From Health Structures	Present in all cases	1832 (A) 692 (C)	1832 (A) 692 (C)
Unnecessary Transport From Health Structures	Benefit	0	4228 (A) 2074 (C)
Transport For Consultation Required By GPs	Benefit	0	48163
TOTAL		**18482 (A) 17342 (C)**	**54223 (A) 50929 (C)**

TABLE VIII. COST-BENEFIT ANALYSIS RESULTS

Expenditure Cause	***Min €***	***Max €***
Costs	16650	16650
Benefits	50263	52391
TOTAL SAVINGS	**33586**	**35740**

IV. DISCUSSION

Although the result of our analysis appear good we should emphasize some limitations of this study:

- the precise number of consultation requiring ambulance transfer are unavailable for some health structures;
- the ambulance costs are an estimate since the precise cost are unavailable;
- for outpatient consultation we used average estimates of distance rather than precise mileages;
- for the patient perspective costs, we excluded data from the Cagliari district.

These limitations probably do not undermine the value of our preliminary analysis, but they do suggest themes for future studies: cost-effectiveness analysis and sensitivity analysis should be designed to enhance the quality of the system evaluation.

Another question left open is that of the relative performance of telemedicine systems: our solution is open and low cost, but about commercial systems? We have yet to compile a similar table of costs for existing commercial telemedicine applications (their prices are not publicly available). Instead, we tabulate some teleconference

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systems (not necessarily dedicated to CHD), that might be used in similar way. TABLE IX summarizes the systems we studied.

TABLE IX. SIMILAR TELEMEDICINE SOLUTIONS

System	***Price***
VSEE [20]	$299/kit/month $49/user/month
Lifesize Communications conference streaming system [21][22]	$2000 to $15000 hw $49/month sw
Cisco TelePresence [23][24]	$ 9900 hw
Tanderberg video communication (Cisco company) [25][26][27]	~$10000 to $30000 for clinical presence system
VIDYO [28][29]	starting at $17000

None of the solutions we list here appear to guarantee the performance offered by our platform, in terms of teleconsultation support and setup/maintenance cost savings.

V. CONCLUSIONS

The preliminary cost-benefit analysis presented in this paper shows that the adoption of the real-time telemedicine solution we developed is potentially useful from a societal perspective. This analysis is local and is focused on a specific situation, but the design principles that guided its development enable it to be applied in other clinical contexts that require operator-dependent diagnostic techniques. At the moment, the telemedicine system is under trial in emergency structures for the FAST (Focused Assessment with Sonography for Trauma) examination. Another added value of the system derives from its adaptability to support learning sessions. In conclusion, the benefits of our telemedicine system confirm the original hypothesis from which we started and encourage us to trial the system on a regional scale, once the an organizational model has been completely defined.

ACKNOWLEDGMENT

The authors wish to thank Gavin Brelstaff, Emiliano Deplano, Emanuela Falqui and Luisa Coraddu for all the support, during the system development and during the analysis presented in this paper.

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The Assessment of Differences in Acceptance of e-Health Applications Between Physicians and Patients with Chronic Diseases

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***Abstract*—The implementation of e-health solutions targeting patients and citizens as users is an important aspect of national policies of development of information technology infrastructure in health care in Poland. The success of these plans is related not only to political decisions but also to the response of potential users. The main objective of the study was the comparison of the level of acceptance of the use of e-health solutions for accomplishment of specific activities demonstrated by physicians and patients with chronic diseases. The analysis presented in the paper was based on the results of two surveys dedicated to the assessment of the views of medical personnel and patients on the importance of e-health in Polish health care system. The survey for physicians was performed among participants of speciality trainings in the period from November 2011 to December 2012 in Krakow, Poland. The survey for patients was carried out among the patients diagnosed with chronic disease who were hospitalized or attended ambulatory visit at three health care centers in Krakow, Poland in the period from mid-December 2011 to mid-February 2012. From 200 questionnaires distributed to physicians, 186 were returned by respondents. The questionnaires for patients were filled by 207 respondents from 230 who were approached. The level of acceptance for specific e-health applications was higher among physicians. The differences were statistically significant in case of all but one application. Interestingly, the applications with highest acceptance in both groups of respondents included online appointment with physician, access to the results of laboratory tests and access to educational resources. In conclusion, it should be stated that physicians reveal significantly higher acceptance of e-health use, but the perception of priorities among specific e-health applications is convergent between physicians and patients.**

Keywords-e-health acceptance; Internet; information and telecommunication technologies; physicians; patients.

I. INTRODUCTION

Chronic care remains one of the greatest challenges for modern health care systems. Patients suffering from chronic disorders require support on long-term basis. There are estimations which indicate that even 40% of citizens living in modern societies are afflicted with chronic medical conditions [1]. Furthermore, the budgets used for support of chronic patients reveal growing trends [2].

As close cooperation and communication between patients and physicians are prerequisites of efficient care, both groups of users should be ready to use proposed e-health solutions. The use of such solutions may enhance repetitive interactions between patients and providers. Nowadays, it is also obvious that patients should be involved in activities related to controlling and treating of disease [3,4]. All these circumstances result in search for more efficient models of care which could be offered to patients with chronic disorders [5-8].

The main objective of the study was the comparison of the level of acceptance of the use of e-health solutions for accomplishment of specific activities demonstrated by physicians and patients with chronic diseases.

The paper consists of five sections. The Introduction section indicates rationale and objective for the study. In the Methods section the methodology of the surveys carried out among patients and physicians is described. The Results section brings the characteristics of both respondents' groups as well as results of comparison of acceptance of specific e-health applications between them. In the Discussion section, short discussion about significance of results is provided. In the final section, the conclusion summarizing obtained results is given. Furthermore, the plans for future research are revealed.

II. METHODS

The comparison of the acceptance of specific e-health applications among patients and physicians was carried out on data obtained from surveys targeting both groups.

The survey designed for physicians was focused on the general use of computers and Internet, the perception of importance and circumstances of e-health in modern health care, and finally, the acceptance for performance of specific health care services in e-health environment. In total, 30 items were included in the questionnaire. The methodology of the survey performed among physicians was described in detail elsewhere [9].

The survey realized among patients covered the issues related to coping with chronic condition, general issues of computer and Internet literacy, the use of information technology (IT) for health-related activities, the perception of e-health feasibility for support of health care and finally, the acceptance of specific functionalities delivered with e-health applications. Further details on the patients survey may be

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found in an earlier published paper [10], focusing exclusively on patients with chronic respiratory diseases.

The items targeting the assessment of the acceptance of concrete e-health applications were compatible both in term of the set of enlisted applications and response scale. Both questionnaires included predominantly closed questions. The responses to the items focused on the opinions of the respondents were based on 5-point Likert scale with neutral option in the middle (from 'decidedly yes' to 'decidedly no').

The survey for physicians was performed among participants of the courses on public health obligatory to participants of all specialities training and organized by Medical Centre of Postgraduate Education, Jagiellonian University, in Krakow, from November 2011 to December 2012. The survey for patients was carried out among the patients diagnosed with chronic disease who were hospitalized or attended ambulatory visit at three health care centers in Krakow, Poland in the period from mid-December 2011 to mid-February 2012. Only patients with established diagnosis of chronic disease were recruited to the survey. Patients, who were hospitalized or admitted to polyclinics for diagnosis of new symptoms, were not included in the study, unless they had previously been diagnosed with a chronic disease.

Both surveys were assessed by Bioethical Committee at Jagiellonian University in Krakow, Poland (decision No KBET/226/B/2011 dated October, 27, 2011 for physicians' survey and decision No KBET/107/B/2011 dated June 30, 2011 for patients' survey). The questionnaires were filled by physicians anonymously. The patients were asked to fill informed consent form. The respondents were informed before the survey that they can withdraw from the study in any moment.

Statistical analysis was carried out with Statistica v.10 Pl (StatSoft Inc, Tulsa, OK, USA) [11]. The descriptive analysis was performed for the variables included in this paper. If not stated otherwise, the frequency of a given response to a specific item was given as a percentage of all valid responses excluding missing responses. The level of acceptance was assessed with 5-point Likert scale. Definite negative option of response was assigned with value of 1, and the most positive opinion with value of 5. The differences in the acceptance level for specific e-health applications were assessed with non-parametric test for independent samples (Mann-Whitney U test).

III. RESULTS

A. Physicians

Characteristics of respondents

Questionnaires were distributed to 200 respondents; filled ones were returned by 186 of them. Five questionnaires were excluded from further analysis due to considerable deficiencies of responses. Women made 65.7% (n=119) of the group of respondents. The mean age of physician who filled the questionnaires was 34.9 (SD=6.4) years, 34.7(SD=6.7) among women and 35.5 (SD=5.9) among men.

There were 29.8% (n=54) of respondents with speciality certificate in internal medicine, 5.5% (n=10) in surgery, 3.9% (n=7) in anesthesiology, 10.5% (n=19) in pediatrics, 2.2% (n=4) in gynecology, and 3.9% (n=7) in family medicine. Other specialities were declared by 27.1% (n=49), and none by 20.4% (n=37) of them. As many as 75.7% (n=137) of respondents were employed in hospitals with at least 200 beds, 6.1% (n=11) in hospitals with 100-200 beds, and 7.2% (n=13) in hospitals <100 beds. Furthermore, 33.1% (n=60) of them worked in polyclinics, and 15.5% (n=28) in private practices.

The use of Internet was confirmed by all participants of the survey (n=181). Among respondents, 2.2% (n=4) used Internet not longer than for 2 years, 7.8% (n=14) for above 2 to 5 years, 30.2% (n=54) for above 5 to 10 years, and 59.8% (n=107) for more than 10 years. Every day use of Internet was declared by 82.3% (n=148) respondents; several times a week but not every day by 16.2% (n=29), and only once a week by 1.1% (n=2). The use of Internet at home was indicated by 96.1% (n=174) of physicians and at work site by 88.4% (n=160). Wireless access to Internet was utilized by 27.1% (n=49) respondents. Detailed characteristics of the physicians who participated in the survey was covered elsewhere [9].

TABLE I. ACCEPTANCE OF SPECIFIC E-HEALTH APPLICATIONS AMONG PHYSICIANS (%, n)

E-health applications	**decidedly no**	**rather no**	**I'm not sure**	**rather yes**	**decidedly yes**
Teleconsultation with physician	7.7 (14)	24.3 (44)	18.8 (34)	30.9 (56)	18.2 (33)
Contact with health care providers in case of doubts	5.0 (9)	6.1 (11)	15.0 (27)	46.7 (84)	27.2 (49)
Telemonitoring of physiological parameters	6.8 (12)	10.2 (18)	15.3 (27)	32.2 (57)	35.6 (63)
Making appointment with physician	0.6 (1)	1.1 (2)	0.6 (1)	16.2 (29)	81.6 (146)
E-diary for chronic patients	1.1 (2)	2.9 (5)	2.9 (5)	34.9 (61	58.3 (102)
Personal Internet health account	0.6 (1)	2.8 (5)	6.6 (12)	23.8 (43)	66.3 (120)
Access to profiled educational resources	0.6 (1)	1.1 (2)	3.3 (6)	27.1 (49)	68.0 (123)
Reporting health status to physician	5.0 (9)	16.7 (30)	16.1 (29)	36.1 (65)	26.1 (47)
Contact with health professional during exacerbations	3.6 (6)	12.3 (22)	10.1 (18)	42.5 (76)	31.8 (57)
Access to laboratory test results	0.6 (1)	1.7 (3)	2.2 (4)	23.5 (42)	72.1 (129)
Renewal of prescriptions	1.7 (3)	7.2 (13)	12.2 (22)	25.0 (45)	53.9 (97)

The acceptance of specific e-health applications potentially feasible for patients with chronic diseases

The results of the survey related to the acceptance of specific e-health solutions feasible for care of patients were included in the Table I. The physicians showed the highest

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acceptance for the use of Internet for making appointments for visit in physician's office or polyclinics by patients (4.76, SD=0.58), for access to the results of laboratory tests (4.64, SD=0.68), for access to educational resources (4.62, SD=0.67), and for the use of personal health account (with repository of medical documentation) (4.56, SD=0.76).

B. Patients

Sociodemographic characteristics of respondents

The survey was carried out in the group of 207 patients receiving care in health care institutions located in Krakow, Poland. There were 65.4% (n=134) women in this groups. Mean age of respondents (n=197) was 49.6 (SD=17.6) years, 48.2 (SD=17.2) among women and 52.4 (SD=17.2) among men. Further sociodemographic data were included in the Table II.

Among patients participating in the survey, 55.1% (n=114) suffered from one chronic disease, others were afflicted with more chronic conditions. The most frequent chronic diseases occurring in respondents were related to cardiovascular system (49.8%, n=103). Other frequent disorders included diabetes (38.2%, n=79), bronchial asthma (18.4%, n=38), diseases of musculoskeletal system (21.3%, n=44), diseases of nervous system (11.1%, n=23), and chronic obstructive pulmonary disease (10.6%, n=22).

TABLE II. SOCIODEMOGRAPHIC CHARACTERISTICS OF PATIENTS RECRUITED TO THE SURVEY

Sociodemographic variables	Category	N	%
Sex	women	134	65.4
	men	71	34.6
Place of residence	rural	68	33.7
	urban <100 000	45	22.3
	urban >100 000	89	44.1
Education*	category A	68	32.9
	category B	65	31.4
	category C	74	35.7
Family status	maried	130	64.0
	unmarried	43	21.2
	widow/widower	22	10.8
	partnership	8	3.9
The number of persons in the household	1	22	10.7
	2	75	36.4
	3	40	19.4
	>3	69	23.6

*Categories established on the basis of Educational. Scientific and Cultural Organization (2011) Revision of the International Standard Classification of Education (ISCED): category A – education lower than 'upper secondary', category B – from 'upper secondary' to 'post-secondary non-tertiary', category C – higher than 'post-secondary non-tertiary'[12]

Computer and Internet use

The use of computer was declared by 65.7% (n=136) of respondents. The duration of computer use above 10 years was indicated by 41.2% (n=56), above 5 to 10 years by 24.3%, and not longer than 5 years by 34.6% of them.

Internet browser, e-mail software and text processor were types of applications used most frequently by computer users (87.5%, n=119; 72.1%, n=98; 52.9%, n=72, respectively). More rarely the respondents indicated spreadsheet programs 30.1%, n=41), data bases (30.9%, n=42) and software supporting company activities (23.5%, n=32).

The use of Internet on their own was declared by 57.5% (n=119) patients, and with help of other person by 11.1% (n=23). No use of Internet was indicated by 31.4% (n=65) of them.

TABLE III. ACCEPTANCE OF SPECIFIC E-HEALTH APPLICATIONS AMONG PATIENTS (%, n)

E-health applications	decidedly no	rather no	I'm not sure	rather yes	decidedly yes
Teleconsultation with physician	13.1 (22)	15.5 (26)	21.4 (36)	33.9 (57)	16.1 (27)
Contact with health care providers in case of doubts	10.4 (17)	12.8 (21)	18.9 (31)	39.0 (64)	18.9 (31)
Telemonitoring of physiological parameters	18.8 (30)	17.1 (29)	27.8 (46)	23.8 (38)	10.6 (17)
Making appointment with physician	7.2 (12)	9.6 (16)	10.2 (17)	25.3 (42)	47.6 (79)
E-diary for chronic paitents	8.8 (14)	11.9 (19)	25.2 (40)	26.4 (42)	27.7 (44)
Personal internet health account	9.8 (16)	8.6 (14)	23.3 (38)	27.0 (44)	31.3 (51)
Access to profiled educational resources	7.5 (12)	9.3 (15)	19.9 (32)	29.8 (48)	33.5 (54)
Reporting health status to physician	12.5 (20)	18.1 (29)	23.8 (38)	22.5 (36)	23.1 (37)
Contact with health professional during exacerbations	10.3 (17)	15.8 (26)	23.6 (39)	29.1 (48)	21.2 (35)
Access to laboratory test results	8.6 (14)	9.9 (16)	21.0 (34)	22.2 (36)	38.3 (62)
Renewal of prescriptions	11.2 (18)	12.4 (20)	19.3 (31)	20.5 (33)	36.6 (59)

Among Internet users, there were 25.0% (n=29) of respondents who used it above 10 years, 37.1% (n=43) above 5 to 10 years, and 37.9% (n=44) not longer than 5 years. Daily use of Internet was confirmed by 67.0% (n=79) of patients using Internet without help of other person, several times a week but not every day by 22.0% (n=26), once a week by 8.5% (n=10) and more rarely by 2.5% (n=3) of them. In the group of independent Internet users, access to Internet at home was indicated by 98.3% (n=117) of respondents, in the work place or at school by 49.6% (n=59), in friends by 6.7% (n=8) and in Internet café by 1.7% (n=2).

The acceptance of specific e-health applications potentially feasible for patients with chronic diseases

The structure of responses on acceptability of specific e-health applications among patients participating in the survey were shown in the Table III. Patients revealed the highest acceptance (mean, SD) for e-health applications enabling appointments to physician's office (3.77, SD=0.57), access to educational resources (3.57, 0.66), access to the results of laboratory tests (3.56, SD=0.67) and renewal of prescriptions (3.49, SD=1.03). The acceptance for the teleconsultation with physician was the lowest from all potential solutions (3.20, SD=1.23).

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C. The comparision of the acceptance of e-health applications between physicians and patients

The comparison of the acceptance of specific e-health applications feasible for patients with chronic diseases between physician and patients revealed uniformly higher level of acceptance among physicians. The differences in the level of acceptance were significantly higher for all but one application (teleconsultation with physician). The details of the analysis were shown in Table IV.

TABLE IV. THE COMPARISION OF THE ACCEPTANCE OF E-HEALTH APPLICATIONS BETWEEN PHYSICIANS AND PATIENTS

E-health applications	**Physicians [mean (SD)]**	**Patients [mean (SD)]**	**corr. Z**	**p value**
Teleconsultation with physician	3.28 (1.15)	3.20 (1.23)	0.688	0.49
Contact with health care providers in case of doubts	3.85 (1.11)	3.34 (1.05)	4.999	<0.001
Telemonitoring of physiological parameters	3.80 (1.11)	2.92 (1.22)	7.376	<0.001
Making appointment with physician	4.77 (1.20)	3.77 (0.57)	9.389	<0.001
E-diary for chronic patients	4.46 (1.12)	3.40 (0.79)	9.687	<0.001
Personal internet health account	4.52 (1.16)	3.48 (0.79)	9.416	<0.001
Access to profiled educational resources	4.61 (1.13)	3.57 (0.66)	9.840	<0.001
Reporting health statuts to physician	3.62 (1.18)	3.20 (1.18)	3.648	<0.001
Contact with health professional during exacerbations	3.87 (1.14)	3.28 (1.10)	5.429	<0.001
Access to laboratory test results	4.65 (1.19)	3.56 (0.67)	9.726	<0.001
Renewal of prescriptions	4.22 (1.24)	3.49 (1.03)	6.287	<0.001

IV. DISCUSSION

The surveys performed in the group of physicians participating in the speciality courses and in the group of patients with chronic conditions revealed significant differences in the level of acceptance between these two groups. Physicians demonstrated higher acceptance for specific application than patients and most differences were statistically significant.

It should be noted that the differences could be attributed not only to perception of e-health feasibility among both groups of respondents but also to the fact that the mean age of physicians was lower than of patients.

V. CONCLUSIONS AND FUTURE WORK

Despite significant differences in the acceptance levels for specific applications between physicians and patients, the e-health applications which were top-ranked by both groups included making appointments with physician, access to the results of laboratory tests and access to educational resources profiled for patients. The author plans to proceed with assessment of the acceptance of e-health solutions by other patients and health professionals groups as well as identification of barriers for e-health growth in Poland.

ACKNOWLEDGMENT

The author acknowledges the help of Elzbieta Brzezicka, M.Sc. and Michal Witkowski, M.Sc. in the survey data entry. The author thanks to Katarzyna Kruczak, MD. PhD., Miroslawa Dzikowska, M.Nurs., Anna Andrychiewicz, M.Nurs., Monika Rucka, M.Nurs., and Bartlomiej Matejko for help in distributing the questionnaire to potential respondents.

This research was supported by the resources of the project No. K/ZDS/003685 at the Jagiellonian University Medical College, and of the project No. 13-0093-10 funded by the National Centre of Research and Development in Poland.

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Open Source Home Care Technology

Technical design and development, user research, cost-benefit analysis, and business modeling

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***Abstract*—This paper presents the work in progress for the Hightech@home project. The aim of this project is to develop technology and knowledge concerning open source home care technology, utilizing open standards. Currently, there is limited availability of high tech sensor and communication technology while costs are high. By producing open source technology we aim at providing a starting point towards interoperability. Hence, increasing availability and lowering costs by avoiding vendor lock-ins. The Hightech@home project consists of five tracks. The first track, the technical design and development, focuses on a portal being generically available through any web browser. The portal will facilitate video contact and transmit and receive data from sensors located in the house, or on the body of the user. Technical design and development is iteratively informed by the user research in the second track. The iterative cycles start with small scale experiments with mock-ups leading to a field study when robust prototypes are available. During this field study, data will also be retrieved to perform a cost-benefit analysis, the third track of the project. To ensure the structural embedding, viable business models are developed in a fourth track. Finally, a fifth track focuses on the facilitation of bachelor students in the Hightech@home project in particular and in eHealth research in general.**

Keywords-home care technology; open source; WebRTC; sensortechnology; user research.

I. INTRODUCTION

The aim of the Hightech@home project is to develop technology and knowledge concerning open source home care technology, utilizing open standards. The choice for open source is based on the current lack of low-cost, high quality, high tech, plug and play home care technology. The choice for open protocols enables interoperability: which most literally unlocks the consumer technology we already have in our homes and which we already carry around.

As far as high tech sensor and communication technology is available for home care, the costs are high. Potential users with the greatest need for this type of technology, e.g. elderly, chronically ill, often lack the required financial means. Vendor lock-in (mostly through the use of closed protocols) is one of the reasons for the high pricing. Customers are dependent on one vendor after an initial choice for home care technology. When there is, for instance, a wish for extending the current technology with additional sensors customers appear to be dependent on the original vendor. Hence, low-cost alternatives are not an option. Although completing a single project will not break through an established vendor lock-in, we aim at producing open source technology and knowledge, thus providing a starting point towards interoperability.

Existing home care technology often requires a technician to install. This not only results in extra costs, but also raises the threshold for people to start using it. Our aim is to design and develop plug and play technology by means of a co-creation process with potential end-users. This co-creation process ensures that customers (clients or patients), informal carers, and carers are able to install the equipment. Furthermore, having interoperability at the centre of development, allows for (re-)use of already existing technology and therefore enable specific use cases which are otherwise not possible or viable.

Designing and developing open standards and open source technology in a co-creation process with potential end-users will not be the only focus of the Hightech@home project. A main research theme of the research group IT (Information Technology) Innovations in Health Care at Windesheim University of Applied Sciences, is the structural embedding of innovations in routine care. The end of an innovative project should not imply the end of the innovation. Too often this is still the case [1]. Initiating the development of a viable business model in an early stage of the project enhances the chance on structural embedding the innovation. The Hightech@home project aims to include this business modelling, also adding a cost-benefit analysis.

In this paper we describe the approach of the five tracks of the Hightech@home project, followed by the preliminary results in the next section. We complete the paper with a conclusion and a description of future work.

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II. APPROACH

The project is structured around four research topics and a fifth goal concerning the structural embedding of eHealth research in the education of our students. The approach of all five tracks is briefly outlined in this section.

A. Technical Design and Development

We envision a portal, to be used at home bringing communication capabilities centred around health-communication. The portal is a framework which can be used to offer different, in general communication, capabilities to the user. The portal should be available through any generic web browser and should be capable of transmitting and receiving video, audio and data streams. The video and audio data streams allow the users to make video calls to other users, whereas the data stream can be used to communicate data from sensors in the house, or on the body. The information gathered from sensors, possibly coupled with the audio and video information can be used by healthcare professionals to remotely assist the user. To realise the above, the design and development consists of fourth tracks.

In the first track we aim to embed open standards based and license free video communications in an open source portal already being developed and partially made available by TriVici Foundation for the community (see [2] – in Dutch). The video communication added to this portal is based on WebRTC (Web Real-Time Communications) [3] and WebSockets for signalling.

Secondly, we will develop and implement secure transfer of sensor signalling and data over WebRTC, with the goal to enable easy and reliable connections using open standards / protocols based sensor technology that is currently available in the (consumer – prosumer) marketplace. This will give meaning to the overall goal of interoperability.

The third track is to interface with the currently under development Smart Optical Sensor and to implement WebRTC and VP8/VP9 to its capabilities. For more information, please see [4].

The fourth track is utilizing newly developed single chip radar technology as a sensory device. This technology is still in its early development phases, and we have yet to determine the goals of this part of the project.

B. User Research

User research is iteratively integrated in the design and development process, leading to a co-creation process. User research starts with the inventory of user requirements and contextual conditions. During early stages of design we use mock-ups in interviews and focus groups. When first prototypes are available potential users will experiment with them in our Telecare Skillslab.

During these interviews and experiments the focus is not only on the technology, but additionally also on important issues such as privacy, legislation, and embedding the technology in daily routines.

When a robust prototype is available, a field study will be carried out. Such a study is the final test for functionality, reliability and usability. Furthermore, during the field study it is explored whether end-users intend to keep using the technology and to what price. A final aim of the field study is to investigate whether the use of the technology leads to the intended effects: more indepency in living at home leading to the same or higher quality of care against lower costs.

The facilities to perform relevant user research have recently been extended. The research group IT Innovations in Health Care established the Telecare Skillslab, not only to contribute to education in eHealth, but also to facilitate telecare research. The Skillslab actually consists of two locations both situated at the campus of Windesheim, separated about 200 m. One of the locations has been furnished as a living accommodation which makes it possible to experiment with domestic applications of sensors in a realistic manner. The other location typically aims at facilitating formal or informal carers, providing care at a distance. Camera's installed in the ceiling provide the researchers with possibilities for non-obtrusive observation. In addition to this interviews and focus groups can be hosted in an informal setting in the living room part of the Skillslab.

C. Cost-benefit Analysis

To ensure the structural embedding of the developed technology in routine care, costs and benefits need to be balanced. Not only should overall costs be evened out with overall benefits, but balance between costs and benefits of single stakeholders within the care chain should also be pursued.

The goal of the cost-benefit analysis in the Hightech@home project is to provide insight in the costs and benefits on the level of single stakeholders within the involved care chain. Relevant data will be collected during the field study.

D. Business Modeling

IT-related business model innovations have become key factors in achieving structural innovation in healthcare [5]. Hence, in former projects [6] we developed a business model approach to be used as an instrument to bridge the gap of innovative eHealth ideas to successful IT-based care services. A main component of this approach is the online webtool, the *eHealth innovation Matrix* ([7] – in Dutch).

When using open source technology, new business models need to be developed. Therefore we will use this eHix-approach during the Hightech@home project. This implies the application of relevant instruments and knowledge as included in all five distinguished phases of the eHix. See Figure 1 for the five phases and examples of knowledge and instruments per phase.

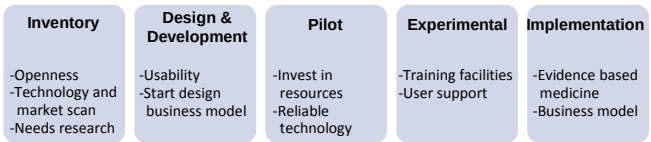

Figure 1. eHix: innovation phases and examples

E. eHealth research in education

Being a University of Applied Sciences, it is important to include students in our research. In this project bachelor Information Technology students are involved both in technical design and development as in the above mentioned research. User research is also performed by Bachelor Health and Welfare students.

To facilitate future involvement of students in our eHealth-projects, an additional aim of the Hightech@home project is the design and development of a digital learning environment. This environment will facilitate students with easy access to all relevant knowledge to provide them with a head start.

III. PRELIMINARY RESULTS

The project Hightech@home started in June 2013 and will conclude at the end of 2014. Hence, at the time of writing the first four months of the project can be considered. This section highlights some preliminary results and lessons learnt from these four months.

A. Technical Design and Development

The portal contains video and audio capabilities to communicate with care professionals and friends. Since the portal itself is made available through the web browser, the video and audio capabilities should also be available there. The benefit of this set-up is that no additional software is required. We use WebRTC [8] to facilitate video and audio in the browser. At this moment WebRTC is available in at least Google Chrome, but implementations in other browsers are likely to be completed in the future. WebRTC makes it possible to communicate peer-to-peer , without the need for a central server. Currently, in our set-up we assume both clients to use the same codec, which makes a translation of the data stream unnecessary. The result is a fully peer-to-peer audio and video connection between two clients.

Setting up this connection between peers, however, requires some administration. We used the Session Initiation Protocol (SIP), with a central Asterisk server for this purpose. After initiation, the connection is completely peer-to-peer and the central server is no longer needed.

B. User Research

Top priority of the involved user researchers, is the selection and inclusion of a specific end-user target group. So far we were not successful in obtaining full commitment of a care organisation, despite principles concerning the involvement of end-users. This puts pressure on the intended co-creation process. Due to political developments in The Netherlands, care organisations need their full attention, available time and staff to focus on their primary processes. Innovation activities are cut back. Hence, involvement in a project like Hightech@home becomes less likely. At the moment of writing we are still aiming at the commitment of a care organisation. Furthermore we are considering alternative options concerning informal carers.

C. Cost-benefit Analysis

To provide insight in the costs and benefits on the level of single stakeholders within the involved care chain, a cost-benefit analysis will be drafted in the Hightech@home project. The relevant data for this analysis will be collected during the field study where the prototype will be tested for functionality, reliability and usability. It is only after exploration whether end-users intend to keep using the technology and to what price and whether the use of the technology leads to the intended effects that this cost-benefit analysis can be drawn up.

D. Business Modeling

Menko et al. described the eHealth innovation Matrix and illustrated the application of its business model framework with an example of an eHealth innovation, namely the DiMove service [6]. In the Hightech@home project the eHix will be applied as well. Both the eHix Scan and the Library will be utilized. The Scan consists of a questionnaire which allows users to determine the status of their project. The Library contains, among other things, templates and checklists to facilitate the innovation process.

Not only will the eHix be applied in the Hightech@home project, but the use of the eHix will also be studied in order to discover opportunities for further improvement and enhancement of the approach. Technical action research (TAR) [9, 10] has been selected to study the use of the eHix in practice. In this approach, the researcher plays three logically separate roles: the developer and the investigator of (in this case) the eHix approach together with a role in which the client is supported in using the eHix to improve the client's eHealth innovation process. In these three roles the eHix will be applied, studied in practice, and possibly improved.

E. eHealth research in education

The project activities of the project Hightech@home are carried out by researchers, lecturers and students from both the programs Bachelor of IT and Bachelor of Health Care. This creates integration of education and research and a multidisciplinary approach. The activities in the various Hightech@home projects should provide a structural assurance in the educational curriculum of IT training. Therefore, after careful consideration of the various forms of imbedding the Hightech@home project activities in the educational curriculum at the start of the project, one of the deliverables of this project is a sustainable learning environment for IT students in the field of e-health and home care technology. Compatible with the current trend in education, this deliverable will take form in a digital learning environment (DLE) created by and for Bachelor of IT students.

The DLE consists of three levels - macro, meso and micro level. The macro level gives the context of e-health and the documentation contains general introductions to e-health in the IT domain. The micro level consists of information on home care technology in the Netherlands. At

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the micro level all documents regarding the Hightech@home project are presented.

The DLE has many benefits. It ensures that students of Information Technology (IT) have access to a high quality of information related to e-health and open high-tech home technology in a quick and in a pleasant way. Using open technology of d-wiki, the DLE is easy to access and has as low cost start up and maintenance [11]. Through independent study of this learning environment the IT student can quickly prepare and act in any e-health project and an open home care technology project almost independently, with less preparation time and little guidance.

After in-depth interviews with various groups of IT students, consultation with researchers and lecturers and after thorough desk research on digital learning, two IT students have drafted the requirements analysis and set up the technical structure of the DLE. The next two months these students will sample the content and present the documentation on the DLE in the appropriate way. In January 2014 the first version of the DLE will be released after formal approval by the project group. Ready for use this DLE will be evaluated and updated methodologically by the next group of IT students working on the Hightech@home project.

IV. CONCLUSION AND FUTURE WORK

In this paper we described the Hightech@home project's ambition to develop technology and knowledge concerning open source home care technology utilizing open standards, to perform user research with prototypes, to draft a cost-benefit analysis, and to develop a viable business model. We also presented the first months of progress of the Hightech@home project.

The main conclusion to be drawn from the current progress is that WebRTC seems both very promising to realise our ambitions and feasible to work with. With guidance from our researchers, the students were able to realise a fully peer-to-peer audio and video connection between two clients.

A second conclusion concerns the high ambitions of the project. For a project lasting only 18 months with limited resources we are quite demanding with our goals set on five different topics: Technical Design and Development, User Research, Cost-benefit Analysis, Business Modelling, and eHealth research in education. Nonetheless we think we can realise our ambitions and hence make a difference in home care by providing low cost plug and play home care technology.

Future work on the project concerns the plans on all five tracks as described, with a high priority focus on including a care organisation in the project team. Beyond the described plans, future work concerns scaling up the project. Several eHealth companies have already shown interest in joining the team if a follow-up project will be funded and started. We conclude from this interest, that open source home care technology is a wanted technology to further develop and investigate.

ACKNOWLEDGMENT

The authors wish to thank TechForFuture, Centre of Expertise HTSM (http://www.techforfuture.nl) for its financial support. The centre is an initiative of Saxion and Windesheim, universities of applied sciences and was established with the support of the Province of Overijssel.

We thank IT students Infrastructure Design and Security for their work on the homecare portal: Ashley Fennema, Patrick van der Graaf, Jeroen van der Linde, Robbert Mulder, Andries Roodbergen, Martijn Rotman. And we thank the IT students Business IT and Management for their work on the Digital Learning Environment: Emiel Hofstede and Jesse Lantinga.

We also thank OpenXs and Castbasics for their cooperation in the Hightech@home project.

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Approaching 2014: Is Telemedicine Assessed from The Social Perspective?

A Brief 2013 Systematic Review

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***Abstract*—Recent reviews in Telemedicine (TM) detected methodological flaws in economic assessment. Our brief review addresses the perspective adoption problem, investigating to what extent adopting a broader point of view could have an impact on TM economic studies and consequential diffusion. Out of 486 articles found, 15 studies were selected for full-text assessment. Most of them showed an improvement in methodology if compared with the past TM economic evaluations. However, only 4 papers reported data from the social perspective and among them 3 presented productivity loss. Although some positive results in economic evaluation were observed, to date it is not clear to what extent TM is paid for by third parties or has to be paid by the patients.**

Keywords-economic evaluation perspective; cost-effectiveness; cost-utility; review;

I. INTRODUCTION

Telemedicine (TM) is a relative recently established field, nonetheless it is dominating the debate in the scientific community. Information and Communication Technologies (ICT) constant improvement resulted in various benefits for the users. In fact it should be considered the revolution in users' life when the ICT reached a wide diffusion. In less than 30 years, the average consumer passed from barely communicating with Total Access Communication System (TACS), to gathering lap-top duties in smart-phones. This overturn in everyday lifestyle, completely changed habits and therefore the time spent in different daily life tasks. While mobile communications and Internet diffusion have already shown to have a positive effect on GDP and productivity growth, [1,2] the same could not be stated for telemedicine. In the global financial crisis setting, resources allocated to the healthcare sector were significantly diminished; this scenario asks for cost-saving initiatives, but also for innovative and effective strategies able to make the healthcare system financially sustainable. Within this framework, Medicare and Medicaid provided reimbursement for many telemedicine programs for preserving high quality healthcare and pursuing a cost-saving strategy in those areas where specialized employees are not available (e.g., rural districts) [3]. The forecasted market value for telecare was predicted to double from $9.8 billion (2010) to $27.3 billion (2016); 18.6% being the compound annual growth rate, having not substantial hinders on its growth [4]. Nevertheless, effectiveness and cost-effectiveness of telemedicine and its related fields are not clear yet. Both early and the most recent literature reviews [5-10] report contradictory results on the actual impact of telemedicine in terms of costs and effectiveness. However, most of the reviewers observed a high prevalence of poor designed and developed studies, probably responsible for reluctance in adopting telemedicine. In addition, it is not clear to what extent telemedicine should be considered an only third-party payer's matter or not. There is a common agreement about cost-utility analysis to be performed adopting National Health Service (NHS) perspective. Nonetheless, estimating only third-party payer's costs could be responsible for partial cost assessment, and consequential partial benefit estimation. NHS perspective disregards all patients' related cost, excluding indirect and out-of-pocket costs. Productivity loss is a very controversial point in economic evaluation in healthcare. In health economics it was extensively discussed whether indirect costs (productivity loss) should be included in Cost-Effectiveness Analysis (CEA), without reaching a final and wide consensus [11,12]. The explanation for that could be found in the necessity for the NHS to optimize resource consumption as it is driven by spending cap issues. However, patients (and potential informal caregivers) perspective could consequentially report extra information able to influence society itself. Other issues frequently disregarded in economic evaluation are direct non-medical costs (i.e., travelling and accommodation expenditures), which account for a considerable amount of resources consumed if considering high prevalence diseases. The societal perspective is able to embrace all these costs, merging NHS costs (medical and not medical direct cost) to patient ones (out-of-pocket medical and non-medical direct cost; indirect and intangible costs). The object of our brief review is to investigate to what extent economic evaluations in telemedicine published up to 2013 were able to capture potential benefits considering the social perspective issue.

The article is composed by five sections. Introduction addresses state of art and the systematic review aim. Methods section describes the procedures used to select the included articles. Results section explores and highlights the main findings. Discussion reports issues and possible solution to assess properly telemedicine. Finally, conclusion accounts for authors considerations.

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II. METHODS

In order to identify all published studies inherent to economic evaluation in telemedicine, a systematic review was conducted throughout the following databases: EBSCO host (Medline; Cinahl; EconLit; PsycInfo); Database of Abstracts of Reviews of Effectiveness (DARE); ISI Databases (Science Citation Index; Social Science Citation Index; Arts and Humanities Citation Index); Embase; NHS Economic Evaluation Database; Health Technology Assessment Database and the Cochrane Databases. The studies included in the review are full economic evaluations according to Drummond [11]; therefore, the following terms were included in the search strategy: Cost-Minimization Analysis (CMA), Cost-Consequences Analysis (CCA), Cost-Effectiveness Analysis (CEA), Cost-Utility Analysis (CUA), Cost-Benefit Analysis (CBA) of telemedicine and its explosion in mesh tree. Studies reporting only costs or only effectiveness were excluded. Other exclusion criteria were: email-only or telephone-only based studies and different languages than English. Results were limited to the period January 1st, 2013 to November, 2013, as previous reviews extensively reported and discussed data and methodological issues [8,10].

III. RESULTS

Once identifying the article titles, duplicates were deleted using MS excel 2013 (Microsoft Corporation). 486 articles were obtained from search strategy terms research. After titles revision 451 articles were excluded because they were not economic evaluation. Abstracts revision has led to exclude 20 articles: 6 considered only cost, 4 were reviews, 3 considered only effectiveness, 2 were study protocols and 5 were excluded for other reasons (telephone based, different language than English, patients preference, validation study). After the abstract assessment, 15 articles were included for full-text evaluation (Figure 1). NHS and Social perspective were the most adopted respectively 10 and 4 studies.

A. NHS perspective

Among the included trials (Table I), the majority adopted the NHS perspective. The whole set of studies was assessing performance of telemonitoring devices in chronic diseases (Heart failure, Chronic Obstructive Pulmonary Disease, Diabetes, Hypertension), reporting in most of the cases utility outcomes (e.g., Quality Adjusted Life Years - QALYs). Time horizon ranged from 6 months to 16 months. Out of 6 decision models (Table II), 4 of them were Markov model-based economic evaluation and 2 decision tree ones. Although most of them adopted a third-party payer point of view, QALY was chosen as effective outcome in 5 studies. The time horizon covered period ranging from 3 years up to lifetime. Beyond clinical trials and decision models, 2 out of 5 studies with various designs (Table III) assessed TM from the NHS perspective. The interventions were compared with results belonging to the same patients, but observed before telemedicine procedure started. No Health Related Quality of Life (HRQOL) outcomes were considered; authors chose monetary benefits or clinical outcomes.

B. Social perspective

Most of the studies assessing costs alongside clinical trials adopted NHS perspective. Nevertheless, Zanaboni et al. [13] showed costs experienced by patients for travelling and private visits in both study arms; however, patients' costs were excluded in CUA. No significant difference in cost for NHS was observed, on the other hand patients in TM arm experienced a lower expense of 100€ per patient/year ($p<0.05$). This difference was detectable in all the patients' related costs (Protocol-defined visits and Emergency Department visits) with exception of "Non-urgent in-office visits", where usual care was less expensive ($p>0.05$). The authors concluded that remote monitoring led to cost saving for patients of about 24% of their cost per year. However, limiting analysis to patients for whom QALY was available, it was considered only NHS costs and was observed a cost reduction of €888.10 per patient over 16 months. Only one Markov model assessed CEA from both the NHS and social perspective [14]. Once household costs were considered, the TM intervention cost increased. However, Rachapelle et al. [14] stated that most of TM costs are related to additional hospital fees rather than to travelling costs or productivity loss. Among studies adopting different design than clinical trials or decision models, 2 of them developed the study from the society point of view. No HRQOL outcomes were used in these studies. Levin et al. [15] performed an uncontrolled retrospective study, assessing cost reduction adopting telemedicine in diabetes teleconsulting in Denmark. In this case, results compared haemoglobin A1c (HbA1c) levels in diabetic patients using TM to Dansk Voksen diabetes database (DVDD) patients' levels [15]. Isetta et al. [16] results compared telemonitoring for low risk newborns with usual care in terms of Emergency Department (ED) accesses. Indirect costs concerning one of the newborn's parents were

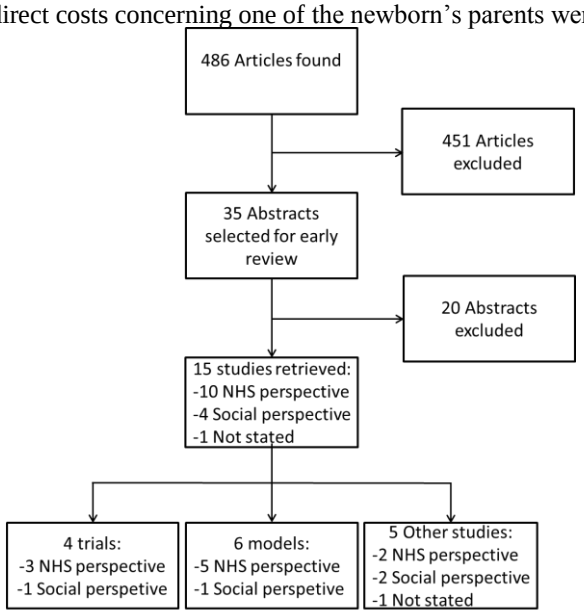

Figure 1. Study selection flow chart.

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assumed to be €15 for missed hour of work, while €30 for travelling expenses to reach the hospital. Sensitivity analyses varied the following costs by ±75%: Emergency Department visit, hospital visit, nurses' salary per hour, travelling to hospital and parents' productivity loss. Even in these cases, the ICER was in favour of telemonitoring.

IV. DISCUSSION

In the last years, many authors questioned the methodological approach to capture costs and effectiveness of telemedicine [5-10]. The most important problems identified were: study design, small samples, limited time horizon, heterogeneous cost-related variables and proxies for effectiveness, control group absence and cost analysis perspective. In the papers published in 2013, we registered a somewhat improvement with regards to most of these elements. In particular, most of the studies retrieved have a sufficiently broad sample and used well-defined cost items and outcomes variables. However, the perspective of analysis remains an unsolved issue. In Italy, it is not clear if telemedicine should be reimbursed or not [13].

In this setting, a narrow perspective is not suitable to properly answer to this question. The societal point of view is by definition the broadest one, embracing NHS, patients and caregivers perspective. From the patients and the caregivers point of view, direct (medical and non-medical), indirect, and intangible costs (HRQOL) should be assessed [11]. In effect, telemedicine, theoretically, could sharply decrease all of these cost items. One of the focal points of telemedicine adoption is abridging distances and consequentially to reduce productivity loss, and delivering high quality healthcare outside the healthcare centre. This has of course an influence in patient's expenditure in terms of travelling and/or accommodation. Zanaboni et al. reported reduction in out-of-pocket costs for in-office and clinic visits. Even if the authors did not report non-medical direct and indirect costs, it is consequential that a reduction in the number of visits was reflected in a reduction in travelling costs and productivity loss for the telemonitoring arm. Likewise, Isetta et al. [16] reported positive results in their cost-effectiveness study including non-medical direct and indirect costs (estimated by assumption). On the other hand, Rachapelle et al. assessed TM intervention adopting the NHS and societal perspective. From the latter point of view, the intervention was no more cost effective in the same timeframe where it was for NHS. In all the cases the introduction or exclusion of productivity loss and travelling/accommodation costs was able to influence the study results.

The other 10 studies reported only the third-party payer's perspective. However, in comparison to the previous reviews, 2013 brought an improvement in terms of methodological reliability in telemedicine studies. Although the number of well-designed studies has somewhat increased, further methodological reliable studies have to be developed in order to confirm telemedicine cost-effectiveness. In addition, the adopted perspective and indirect cost assessment still represent a pivotal unsolved point. Introduction of indirect cost in CEA and CUA was extensively discussed; the main issues raised in the literature were equity, measurement, double counting in HRQOL benefits and opportunity cost [17]. Of course, to convert productivity loss in monetary terms, therefore, limiting it to employed patients, could influence the equity purpose in healthcare, giving priority to employed patients [18]. However, unpaid job could be involved in the analysis attempting to overcome this problem (e.g., considering the avert cost for the closest paid job) [17].

Another important issue to be considered is the measurement of indirect costs, as there is little agreement about what methods among human capital or friction approach is the best in capturing indirect cost. The first one estimating the productivity gain as an averted earning, while the latter depend on the productivity reduction of each patient during the condition and the amount of time (friction period) required to completely restore patient's productivity. Double counting point concerns about whether the observed monetarized outcome (productivity loss) has been fully incorporated in the non-monetarized effectiveness unit. Therefore, double counting could be avoidable considering clinical outcomes instead of HRQOL ones, as in this case outcomes would not express patient's preferences. However, it would lead to lose all the comparability and generalization advantages in using HRQOL outcomes like QALYs. Regarding to this topic Olsen et al. [19] stated that whether the preference based outcome did not report dimension clearly describing income changes related to health gain, it is not possible to know if the patient provided or not these data in his/her utility. In our review the productivity loss was included in 3 studies [14-16], two of them assess indirect cost by assumption, while Rachapelle and colleagues reported productivity loss only for those who had a paid job. On the other hand, Isetta et al. [16] included an estimation of indirect cost for only one of the newborn parents.

A constrained number of studies adopted a broad perspective, and even a smaller number introduced productivity loss. In a public healthcare setting, opportunity costs should be carefully assessed. Although NHS expenditure reduction is straightforward to assess, assessing productivity gain is more complex. Let us consider a hypothetic innovative procedure to be no more expensive than usual care from the NHS perspective, but less expensive from the societal one, the additional resources obtained could be invested directly or indirectly in healthcare again. This would be reflected in extended budget for every single activity able to influence QALYs in favour to the least expensive procedure from social perspective [17].

V. CONCLUSION

Although the controversial issue about including indirect costs in CUA, societal perspective should be adopted considering non-medical direct costs, while productivity loss could be assessed in terms of usual activities loss, but not included in CUA. This would report all the most remarkable

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items of cost and highlight indirect gains (included in QALY, but perhaps hidden in it), resulting in the best informing data for policymakers.

Further methodologically robust studies should be designed and conducted in order to drive both the adopters and the policy makers to more informed and reliable investment decisions.

ACKNOWLEDGMENT

The authors thank: Ms Carla Papa and Ms Maria Teresa Nevigato for the help in retrieving all the articles.

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TABLE I. CLINICAL TRIAL BASED ECONOMIC ANALYSES.

Clinical-trial	Features				
	Population	**Study design**	**Intervention description**	**Data provided**	**Results**
Henderson et al. 2013[20]	1'573 patients with chronic diseases: Heart failure, chronic obstructive pulmonary disease or diabetes. Mean age: 71 years.	Economic evaluation based on a pragmatic, cluster randomized controlled trial. Perspective: NHS. Time horizon: 1 year.	Intervention: Telemonitoring in addition to the usual care. Control: Usual care (UC).	Costs: Telehealth cost, self-reported service use data. Effectiveness outcomes: QALY.	ICER: £92'000/QALY (£79'000/QALY project mana From no capability to full capability: £98'000 with WTP: £30000). Sensitivity analyses: a) 80%, TM cost reduction: £539 (34%probabi b) TM Cost reduction (80%) combined with hi £12'000/QALY. (61% cost-effective probabili
Boyne et al. 2013[21]	382 patients with congestive heart failure Mean age: 71 years.	Multicentre randomized controlled trial. Perspective: NHS. Time horizon: 1 year.	Intervention: Telemonitoring device connected to telephone line. Control: Usual Care.	Costs: direct medical costs, telephone consultation, telemonitoring, ambulance, caregiver-patient phone contact (paid by NHS). Effectiveness outcomes: QALY.	Costs: Total costs: €16'687 (TM) vs €16'561 (UC) (n Physiotherapy costs TM costs €46 more than U ICER (TM vs UC) €40'321/QALY (48% cost €50'000). Subgroup analysis: HF duration ≤18 months probability TM to co HF duration ≥18 months probability TM to co
Stoddart et al. 2013[22]	401 patients with uncontrolled hypertension Mean age: 60.6 years.	Pragmatic randomized controlled trial. Perspective: NHS. Time horizon: 6 months.	Intervention: Telemonitoring based service for the management of uncontrolled hypertension. Control: Usual care.	Direct Costs: Outpatients, nurse consultations emergency telephone, ER visits; drugs. Effectiveness Outcomes: Mean daytime systolic ambulatory blood pressure (SABP).	Cost: Mean difference (TM vs UC) cost-patient per € Effectiveness Outcome: SABP difference (6 months): -6,05 mm Hg (T Mean difference between TM-UC (6 months):
Zanaboni et al. 2013 [13]	200 patients heart failure patients implanted. Mean age: not stated, TM median age: 66 years. UC median age: 69 years.	Prospective, randomized, open, multicentre clinical trial. Perspective: NHS/patient. Time horizon: 16 months.	Intervention: Wireless implantable defibrillator. Control: Usual care.	NHS costs: Direct medical costs, TM follow-up. Patient cost: Outpatient private visits; ED visits, out-of-pocket expenses. Effectiveness outcomes: QALY.	NHS cost: Mean cost per patient (1 year): €1'9 €2'130.01(UC);(p=0.80). Patient cost: Mean cost per patient (1 year): €3 (UC);(p=0.01). Cost-utility analysis: Mean cost per patient (16 €2'962.80 (UC);(p=0.33). QALYs gained (16 months):1.03 (TM) vs 0.97 Even if a €900 fee would be applied to TM, th be negative. (i.e., TM is cost-effective and dominant solutio

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TABLE II. DECISION MODEL BASED ECONOMIC ANALYSES (PART I)

Decision model	Features				
	Population	**Study design**	**Intervention description**	**Data provided**	**Results**
Thokala et al. 2013 [23]	7'572 patients [24]: Discharged from Heart Failure related hospitalization at most 28 days. Mean age: 65.5 years.	Cost-effectiveness Markov model. Perspective: NHS. Time horizon: 38 months.	Intervention: Home TM. Control: Structured telephone support (human based); Structured telephone Support (Human-machine interface).	Costs: Telemonitoring costs (after initial discharge only) direct costs, repeat hospitalization cost. Effectiveness Outcomes: QALY, Death probability.	Base case analysis (House HF study included): ICER: £11'873 (40%cost-effective TM probability with WTP: House HF study excluded: ICER:£ 6'942 (73% cost-effective TM probability with WTP
Kirkizlar et al. 2013 [25]	900 diabetic patients (type 1 and type 2) belonging to those enrolled in the medical centre before or after the teleretinal screening (2005) [26,27]. Mean age: not clearly stated.	Retrospective cohort study plus Markov model for cost-effectiveness analysis. Perspective: NHS. Time horizon: patient's death or at 99 years.	Intervention: Telemedicine screening program aimed to detect diabetic retinopathy. Control: No control group.	Costs: TM costs, UC costs (ophthalmologist visit, scatter photocoagulation and focal photocoagulation), Annual care for a blind person. Effectiveness outcomes: Macular edema, diabetic retinopathy, blindness and QALY.	Teleretinal screening showed to be cost-effecti 3'000patients. (WTP: $50'000).
Rachapelle et al. 2013[14]	Hypothetical cohort of 1'000 rural unscreened diabetic patients. Mean Age: 40.0 years.	Markov model to perform a cost–utility analysis. Perspective: Society. Time horizon: 25 years.	Intervention: Telemedicine screening program aimed to detect diabetic retinopathy. Control: No screening program.	NHS Costs: Telemedicine screening retinal examinations, laser photocoagulation. Patients perspective cost: Travel, food, accommodation, hospital fees, drugs and productivity loss. Effectiveness outcome: QALY.	ICERs : NHS perspective: Once in lifetime screening: $1'320/QALY. (Inside cost-effective range: $1'061 to $3'183/ Annual screening: $4'029/QALY (outside cost ICER for twice in lifetime, 1 every 5, 3 or 2 ye effective range. Social perspective: ICERs for once or twice in a lifetime and every (ICER range$1'061–3'183/QALY) ICER ever longer cost-effective in this setting.
Mistry et al. 2013 [28]	4'786 Standard risk women to deliver babies with congenital heart disease(CHD) [29]. Mean age: not clearly stated.	Decision tree model based cost-effectiveness analysis. Perspective: NHS. Time horizon: 15 months.	Intervention: Store-and-forward telemedicine first consultation for families with traditional CHD risk. Control: No telemedicine screening.	Cost: Telemedicine system costs, lifetime costs for children with and without CHD. Effectiveness outcomes: Lifetime outcomes for children with and without CHD, QALY.	ICERs: Base-case deterministic analysis: No woman receives TM: £12'906; QALY: 23 All women receive TM (50% replacement for £12'876; QALY: 23.28 (Dominant). Base-case probabilistic analysis: No woman receives TM: £12'880; QALY 23. All women receive TM (50% replacement for £12'850; QALY: 23.28 (Dominant). Almost 100%. cost-effective probability with £20'000/QALY.

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TABLE II. DECISION MODEL BASED ECONOMIC ANALYSES (PART II)

Decision model	Features				
	Population	**Study design**	**Intervention description**	**Data provided**	**Results**
Kaambwa et al. 2013[30]	Patients with hypertension belonging to TASMINH2 trial.[31] Mean age: 66.0 years.	Markov model-based probabilistic cost-effectiveness analysis. Perspective: NHS. Time horizon: 35 years.	Intervention: Hypertension TM device. Control: Usual care.	Costs: Hospitalization, outpatient visits, primary care consultations, drugs, equipment, training and equipment replacement (five yearly). Effectiveness outcome: QALY.	ICERs: Self-management vs UC: €1'891/QALY(male €5'733/QALY (females) 99% cost-effective pr with a WTP: €23'000/QALY. Sensitivity analysis: All ICERs remained belo decreased of 20% or 36% (intervention applie intervention beginning, for male and female).T maintained all ICERs below 23'000€, after 5 y 5, 6 and 15 years after the intervention start fo
Switzer et al. 2013 [32]	1'112 acute ischemic stroke (AIS) patients from Georgia Health Sciences University and the Mayo Clinic telestroke networks (unpublished data) Mean age: not stated.	Cost-effectiveness decision tree Perspective: NHS. Time horizon: 5 year.	Intervention: Hub and spoke telestroke network. Control: No network.	Costs: Telestroke costs, treatment costs for AIS and reimbursements. Effectiveness outcomes: Discharge (defined by treatment with intravenous thrombolysis), endovascular stroke therapy, and on set to treatment time.	Base case analysis: -$358'435 per year TM network vs without (fi Effectiveness outcomes: 114 fewer AIS hub-hospital admission per yea

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TABLE III. OTHER STUDY DESIGN ECONOMIC ANALYSES

Other study design	Features				
	Population	**Study design**	**Interventions description**	**Data provided**	**Results**
Chen et al. 2013[33]	141 cardiovascular disease patients. Mean age: 68.5 years.	Non concurrent prospective study Perspective: NHS. Time horizon: 1 year.	Intervention: TM and Cardiologist consultation (24 hours). Control: TM patients observed for 6 months before TM start (usual care).	Direct costs: outpatient visits, hospitalization, total cost (all causes) Effectiveness outcomes: Admission rates, length of hospital stay.	Cost pre-post TM: Inpatient care: - US $511.52 patient/month. Emergency room (ER): +US $9.05 per patient/ Outpatients: +US $56.76 per patient/month. Total cost (all-causes):-US $445.75 per patient/
Levin et al. 2013 [15]	78 patients: 23 type 1 diabetes mellitus (T1DM) 55 type 2 diabetes mellitus (T2DM). Mean age: 66.4 years.	Uncontrolled retrospective study Perspective: Society. Time horizon: ≥6 months of Telemedicine.	Intervention: Telemedicine consultations to diabetes parameters. Control: intervention group compared to Danish database [34].	Direct non-medical cost: Travelling expenses Indirect cost: Productivity loss (assumption) Effectiveness Outcomes HbA1c level.	Cost reduction range: $9'430-$11'170 (TM vs UC). Effectiveness Outcomes: HbA1c level reduction: T2DM 7.4% (TM) vs 7 T1DM 8.0 % (TM) vs 7.9% (p>0.05).
Paré et al. 2013 [35]	95 patients with heart failure or hypertension or diabetes, or COPD patients. Mean age: 70.0 years.	Ambispective cohort cost minimization study Perspective: NHS. Time horizon: 21 months (12 months before, 4 months home care; 4 months after TM).	Personalized TM to check various health parameters. Control: TM patients data before enrolment (usual care).	Direct Costs: ER Visits, Hospitalizations, Length of Stay, Nurse Home Visits, Home telemonitoring. Effectiveness Outcomes: Assumption of non-inferiority for TM respect to UC.	Total costs: Pre TM: $3'840 . During and after TM: $2'283. Effectiveness Outcomes: Assumed to be equal to UC.
Isetta et al. 2013[16]	230 low risk newborns discharged Mean age: N/A (newborns).	Retrospective cohort study. Perspective: Society. Time horizon: at most 2 months (the baby had to reach an appropriate weight condition).	Intervention: Web telemonitoring. Control: Usual care.	Direct costs: ED visits, hospital visits, and web monitoring nursing, travelling(assumption) Indirect costs: Productivity loss (assumption) Effectiveness Outcomes: ED accesses number.	Cost: Web TM follow-up cost: €86.1 per patient duri Hospital-based follow-up cost: €182.1 per patie Effectiveness Outcomes: ED return rate: UC follow-up: 15.8%; TM: 5.6 ICER: -941.2€. Sensitive analysis: One-way: Varying ±75% the cost, Internet-based follow-u TM.
Akematsu et al. 2013[36]	208 patients with various diseases (Chronic and not chronic conditions). Mean age: 75.7 years.	Regression model to assess cost reduction adopting telecare. Perspective: not stated Time horizon: 7 years.	Intervention: Telemonitoring Control: Usual care.	Costs: Medical expenditures Effectiveness outcomes: Days of treatment.	All diseases: Telecare had a negative coefficient for number medical expenditure (p<0.05). Author stated an because autocorrelation under the 1% of signifi Chronic condition: Coefficient for telecare use: medical expenditur of treatment (-4.2) (p<0.05). Only hypertension coefficient for medical expenditure(+6885.39) a (+9.06)(p<0.01).The author concluded observin for treatment days (4.2 days) and medical exper

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The Future of e-Health

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Abstract- **The European Union has promoted several actions on health. The document accompanying the "e-Health"Action Plan 2012-2020, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – "e-Health Action Plan 2012-2020" - An innovative approach to healthcare for the 21st century.COM (2012) 736, describes the vision of e-Health in Europe in line with the objectives of the Europe 2020 Strategy and the Digital Agenda for Europe. The Action Plan presents and consolidates actions to exploit the potential of e-Health, describes the role of the European Union and calls on member states and stakeholders to collaborate with each other. In this paper, the difficulties that affect the spread of e-Health and some ethical aspects of the doctor-patient relationship and the protection of health data are considered. It is clear that the adoption and diffusion of e-Health across borders is a priority for the European Union.**

Keywords-cross-border healthcare, ethical and legal problems

I. INTRODUCTION

E-Health, in which healthcare and resources are transferred by electronic means, is a relatively recent term for the practice of healthcare supported by electronic processes. It is thought that in time with the spread of new technologies such as the Internet, this practice will become more efficient. Therefore, the healthcare sector has considerable potential for growth yet faces numerous challenges in terms of efficiency, as well as financial and social sustainability.

To meet these challenges, several actions on health have been promoted by the European Union. Figure 1 summarizes the main initiatives at European and Italian level in the field of e-Health from 2008 to 2013 [1].

Decision no. 1786/2002/EC of the European Parliament and of the Council of 23 September 2002 introduced a program of Community action in the field of public health [2] and was the first integrated Community programme in this field.

The Digital Agenda proposed by the European Commission is an important part of the Europe 2020 Strategy as it aims to better exploit the potential of Information and Communication Technologies (ICT) to foster innovation, economic growth and progress in the European Union.

For the first time, Directive 2011/24/EU on the application of patients' rights in cross-border healthcare established the rights of patients in Europe who wish to seek healthcare in another member state and be reimbursed for it [3]. The right to healthcare in other member states existed prior to adoption of this Directive; various European Union regulations apply to unexpected medical treatment that might be necessary during a temporary stay abroad (Regulation No. 883/2004 on the coordination of social security systems, and the European Health Insurance Card) [4].

In May 2011, a task force of leading personalities in the field of politics, health and Information and Communication Technologies was established to analyze the role played by technology in addressing the major challenges to the healthcare industry.

The European guidelines for Patient Summaries (2013), provided for by Directive 2011/24, define the data content of the patient summary: a collection of information photographing the clinical condition and health of every citizen [3].

This information can be electronically exchanged between member states to support healthcare for european citizens in any country of the European Union. Each state shall establish a system of storing sensitive information that is in line with the standards of data protection.

Among the Italian initiatives in the field of eHealth is the implementation of Electronic Health Records that contain all the clinical information of the patient and collect digital documents relating to health and social health related

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clinical events. This information will allow decisions of a medical nature to be made much faster, which is especially important in emergency situations.

The ePrescription service allows the electronic prescription of medicine by a legally authorised physician. The prescription is created using specific software and electronically transmitted to the pharmacist. Information relating to drugs dispensed by the pharmacist is then transmitted to the system that manages the electronic patient record in their country of origin.

The process of dematerialization of health records will benefit the organization and management.

The service of electronic transmission of medical certificates allows you to fully automate and digitize the entire process that originates with the production of medical certificates and certificates of illness by the doctor and ends with the transmission, by the worker, certificates to employers.

These initiatives demonstrate how e-Health is an important element of the " e Europe " strategy .

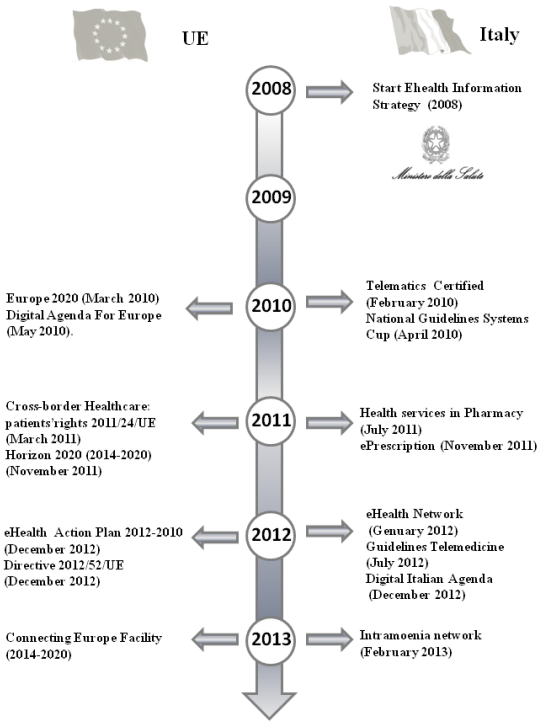

Fig. 1 Initiatives at European and Italian level in e-Health from 2008 to 2013; Board of Health, Italy [1].

II. STATE OF THE ART

In recent years, the development of wireless and mobile networks has encouraged the application of mobile healthcare systems. An important issue is security, as many patients have privacy concerns when it comes to sharing personal information on open channels. These issues must be dealt with and mobile systems might be improved [5]. One challenge is the time that it takes to obtain treatment. This has been addressed by a study which analyses the benefits of telematic services and the use of mobile and wireless devices to develop models that aid the transfer of healthcare. Telematic system requirements which can improve time to treatment for emergency services [6].

The application of healthcare information systems has been shown to assist elderly residents of nursing homes. The use of a web application to collect patient data, creating a personalised electronic file for the residents, has helped physicians to manage the nursing home and the condition of their patients [7].

In the development of e-Health, it is important that attention is focused on the interests of the patient.

III. METHODOLOGY

Among the various initiatives taken by the European Union in the field of eHealth, the following have been analysed: eHealth Action Plan 2012-2020, Directive 2011/24/EU [3] and Law August 6, 2013, n. 96 [8], with which Italy launched the final phase of the formal transposition of Directive 2011/24/EU [3] **.** The Action Plan aims to guide healthcare workers and patients in times of austerity, investing in research to create personalised medicine and cost efficient, high quality care for all.

IV. DISCUSSION

The European Union is interested in strengthening and promoting the efforts of member states in the field of e-Health because this practice can bring several benefits to citizens and health professionals: offering user-friendly, secure systems that allow patients to take greater control over the management of their healthcare [9]. E-Health includes the practice of telemedicine, which uses information technologies and telecommunication to provide healthcare at a distance; finally, as e-Health is the third largest industry in the health sector, it is also an important part of economic growth. As its adoption increases, it will also be possible to reduce spending on healthcare. Finally, it must be considered that in terms of economic advantages, telemedicine can greatly reduce time spent off work and minimize waiting times for physicians and patients alike.

The European Union's population is also rapidly aging: the percentage of the elderly (65 +) and very elderly (80 +)

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will increase from 17.4 % in 2010 to 30.0% in 2060 and from 4.7 % in 2010 to 12.1% in 2060; this will also require a better quality of services and healthcare [10].

However, there are still obstacles to the full deployment of eHealth.

First, we should consider legal barriers:

1) Privacy

Medical privacy, or the practice of keeping information about a patient strictly confidential, has to be ensured. This involves conversational discretion on the part of healthcare providers, and the security of medical records [11]. Privacy can be considered a barrier to e-Health. In e-Health, there is an electronic transfer of patient medical data and medical records to the physician. Healthcare providers must comply with data protection, and in doing so must take significant action to comply with legal restrictions [12]. Telemedicine is challenged by unclear legal regulation for some practices.

2) Security

Data protection in e-Health is very important. There are security issues in the storage of medical data so that it can be accessed by doctors and patients over the web. The confidentiality of medical information is valued very highly by consumers, but there is a real risk that sensitive information might be compromised through electronic storage and transmission [12].

Medical professionals and telemedicine users must always be aware of one of the most important principles of medical practice, that is to say the respect of privacy. In particular, in e-Health we talk about 'sensitive personal data' (relating to "physical or mental health or condition").

Then, there is the question of the type of information that is handled: should there be full data disclosure or just the minimum data needed to form a diagnosis? The patient must be informed about this and must consent to any procedures.

Another topic is access to this data. Information must be collected and recorded in such a way that no outside person can see, copy or download it and clearance should be reserved for the parties concerned (patient, attending physician, or telemedicine specialist). This is one of the occasions in which the Information and Communications Technology specialist must support the medical team. For example, electronic patient files should be accessed only by the treating physician and medical assistants according to necessity, including the possibility of emergency access. Any access beyond that should require a special consent of the patient.

Some questions remain open but one thing is for sure: doctors should respect and maintain confidentiality; if not for legal, at least for ethical reasons.

3) Licensure

The license for a physician is essential to ensure safety. The licensure of physicians is a regulatory function that is performed by the individual state. When physicians practice e-Health across state borders by treating a patient in a different state; there is often no way of knowing if they have licensure, are under suspension, or have lost their license.

4) Other barriers

Due to the exclusive nature of the Information and Communication Technologies equipment used in telemedicine services, it is very expensive to buy and install the equipment necessary for practicing telemedicine.

Another limitation may be the lack of general guidelines for the practice of international telemedicine or rules that can standardize the use of telemedicine across member states. Guidelines should be seen as a set of recommendations that aim to facilitate the exchange of data across borders, understand what data is to be included in datasets and meet organizational and technical requirements.

Therefore, a study of existing legal barriers between member states is important for the diffusion of e-Health in Europe, and to this end the European Commision has created a legal framework for e-Health. The Directive on the application of patients' rights in cross-border healthcare will contribute to achieving this objective, as it defines what rights relating to such assistance remain with the patient across borders.

The document of the Commission services on the applicability of the current legal framework to telemedicine services (Commission Staff Working Paper on the applicability of existing European Union legal framework to telemedicine services) clarifies that European Union legislation is applicable to issues related to reimbursement, responsibilities, and authorizations of healthcare data protection in relation to the provision of telemedicine services across borders.

Since 2013, the Commission has initiated a dialogue on the legal aspects related to e-Health. It should be remembered that rules which serve to safeguard and protect people can not be totally eliminated, but it is possible to standardize rules among the states.

There are also some technical problems relating to the adoption of e-Health, such as:

1) Unavailability of cell phone network coverage or a network with weak reception, especially in remote areas or in the desert.

2) Unavailability of Internet or slow connection.

3) Unavailability or improper equipment used in e-Healthcare such as computers, printers, scanners, a good quality camera, as well as specific telemedicine devices.

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4) Absence of effective information technology systems and supporting infrastructure, which represents a major barrier to initiate a telemedicine program. For example, the method of data transmission must have adequate bandwidth to transmit large amounts of data quickly, accurately, and safely.

Organizational problems:

A standard verification process for telemedicine providers is lacking.

Financial issues are delaying a more rapid uptake of telemedicine.

There is a lack of coordination between clinicians and technology developers.

Standards and guidelines for best practices in telemedicine should be better defined and made more consistent.

To overcome some of these obstacles to the Action Plan of the European Union, a greater interoperability of e-Health services is recommended. This aspect of interoperability concerns the way in which organizations, such as public administrations in different member states, shall cooperate to achieve common goals.

To create confidence in e-Health it is necessary to ensure an efficient protection of health data.

In January 2012, the Commission adopted a proposal for a Regulation establishing a comprehensive framework for European Union data protection aimed at updating the current rules and greater harmonization [13].

Cultural Barriers

Another important limit to e-Health are cultural barriers. These might be due to lack of available information about the practice of e-health, or the unwillingness of some physicians to adapt clinical paradigms for telemedicine applications. Understandably, there is a general lack of confidence in the adoption of e-health, due to the fact that the physician need not be present to offer health solutions. Often, physicians are not even aware of the existence of telemedicine services and, in fact, can often only approach e-Health through postgraduate training, Master's Degrees or university courses. If the possibilities of telemedicine are unknown, neither doctors nor patients will be interested in taking advantage of the multiple opportunities it offers.

In the changing cultural conditions in which it is practiced today, the relationship between doctor and patient is mediated by an instrument of a legal nature which is known as "informed consent."

In principle, informed consent is not reducible to a simple information sheet; it must be signed by the patient (or someone for him): it is the reference point of the doctor-patient relationship, since it contains what is to be done in the present moment from the clinical point of view, on which interpersonal respect, concern for others, the recognition of professionalism and attention to dialogue should be exercised [13].

Therefore, one of the problems in the use of telemedicine is the selection and adoption of an informed consent form suitable for use in e-Health.

Medicine which works on human subjects is also inextricably linked to values such as friendship and justice, and the sick person is not a mere object of the physician's art but is always subject to a therapeutic relationship.

In Italy, Law August 6, 2013, n . 96 Delegation to the Government for the transposition of European directives and the implementation of other acts of the European Union - Delegation of European Law, 2013, with which the final phase of the formal transposition of Directive 2011/24/EU commenced, entered into force on 4 December, 2013 [8].

Until 4 December 2013, people were subject to the rights provided for in the regulations that already governed the assistance of the citizen, in a country other than their own, but this Directive can now be applied. The Directive ensures that citizens have the right to freely choose the place where to seek treatment within the EU.

Important aspects are: prior authorization, reimbursement and border agreements. Each state should now have a system of prior authorization and may also provide a list of health benefits for which permission will not be required.

Reimbursement: a member state will determine at local, regional and national level, the healthcare for which an insured person is entitled to reimbursement, as well as their level of coverage.

In addition to authorizations and reimbursements, agreements between the States which should cooperate to facilitate the implementation of the Directive will be required.

V. CONCLUSION

E-Health is not just "selling" a service or a product; it is a relationship that, while never replacing the human relationship between physician and patient, may still be useful in the treatment of certain diseases. It could also help patients to emerge from the isolation an illness can bring.

The patient must always be protected when accessing online services, for it is necessary to know which sites are safe. On this topic, states must intervene. In addition to the initiatives of the European Union and co-operation between individual states, it is important to promote initiatives aimed at a greater knowledge of telemedicine. It is important to increase confidence among patients but also among

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healthcare workers.

The transmission of knowledge through education (including through training courses, University courses and Master's degrees) can break down barriers more than the implementation of a document, although this is also important and fundamental.

By using cross-border e-Health it will be possible to ensure continuity of care and assistance for citizens. If the system is well built, it can ensure quality healthcare and the adoption of state of the art techniques, in particular concerning the diagnosis and treatment of rare diseases, will ensure the system is more effective and might also reduce healthcare costs in the long run.

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Economic impact of remote specialist consultations using videoconferencing: an economic model based on data from randomised controlled trials

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Abstract – **The University Hospital of North Norway plans to replace some of the outpatient consultations with real-time telemedicine. It has been estimated that 7000 consultations annually can be handled remotely by videoconferencing. As part of this initiative, a project assessing the economic impact of using videoconferencing at scale has been initiated. Cost-effectiveness will be assessed using models based on data from existing randomised controlled trials. A literature search in relevant databases has been conducted to collect data on patient flow and clinical effectiveness (QALYs). Data on the cost parameters will be collected locally. The data on costs and effectiveness parameters will then be synthesised to estimate average group values. Probabilistic methods will be used for estimation of expected outcomes and for sensitivity analysis. This paper describes the planned modelling evaluation, reports the results from the literature review and outlines potential model structures.**

Keywords – cost-effectiveness analysis, decision analytical modelling, telemedicine, videoconferencing, randomised trials, literature review, and economic model.

I. INTRODUCTION

Telemedicine has been around for almost two decades, but is still viewed as outside the mainstream of most health care services (except possibly for radiology) [1]. Implementing telemedicine technologies as part of routine health care delivery requires evidence of the following: its technical feasibility; its practicality in a clinical setting; and finally its being worthwhile, that is, that the additional costs are met with savings or improvements in health outcomes [2, 3]. Main arguments for introducing telemedicine services has been to decrease costs, improve efficiency and increase access in health care delivery. These cost savings and efficiency potentials make economic evaluation of central importance to telemedicine evaluations. To be able to make well-informed resource decisions, information on costs and consequences associated with these decisions must be available. Information on costs and consequences can broadly be collected in two ways: alongside trials and observational studies (primary data); and, from the existing literature (secondary data) [4, 5].

A. Economic data

New primary economic data can be collected alongside randomised clinical trials, non-randomised interventions and observational studies (general issues in economic evaluations are common to all these) [5].

Randomised trials are designed to investigate the relative effectiveness of different medical interventions [6]. The most important advantage of randomisation is that it minimises allocation bias and balances other factors that might affect the result, both known and unknown. Strictly controlled trials are not very common in telemedicine research for practical reasons, nor are they well suited for economic evaluations. The more controlled a trial is the less can be concluded about how much the intervention costs and how well it works for normal caseloads in everyday practice. The trial context is often very different from real-world decisions and conditions that will improve internal validity in randomised controlled trials will undermine the economic evaluation [7]. Real-setting clinical trials are in many telemedicine situations both time consuming, difficult to conduct (too few participants) and expensive to run. This often leaves decision-makers without information about clinical and economic consequences of different telemedicine interventions.

Another way to inform decision-makers is to use the best available evidence from existing sources and decision models. Secondary data can come from clinical trials, observational studies meta-analysis and case reports found in the literature. Data can also be found in databases and administrative records. Decision models provide a means to bringing this evidence together in a systematic way.

B. When to Model

A well-designed model is essentially a tool that can simulate or mimic a clinical trial [8]. Models can simulate different scenarios by making explicit assumptions about the incidence, prognosis, duration, benefits, health-related quality of life and costs. It allows one to investigate how cost and benefits might change if the values of key parameters in the model change. The purpose of modelling is not to make unconditional claims about the

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consequences of an intervention, but rather to reveal the relation between assumptions and outcomes [9].

Whether to use new trial-based data or existing data and decision models in economic evaluation of telemedicine should be seen in relation to the objective and role of the study and the viewpoint of those who are expected to use the results [7]. A randomised trial focuses on particular measurements for specific patients in one specific setting. These are essential in establishing safety and clinical effectiveness as a first stage in developing telemedicine applications. The evidence base for decision-making should be based on the best available measurements on clinical and economic outcomes and these come from trials. Decision models are useful in situations where more evidence is required than can be obtained in one single trial. Furthermore, in a situation where a decision has to be made in the absence of evidence from trials, modelling can help structure the problem, assess potential pathways and identify the level of uncertainty.

In this paper, we describe an economic evaluation based on existing data and modelling techniques. The paper is structured as follows: Section II provides the background and includes an overview of the local context, the use of clinical videoconferencing, and the rationale and aim of this project. Section III outlines the research approach and provides an overview of the modelling study and the data collection. Section IV reports the results of the literature search and propose two preliminary model structures. Section V discusses implications and limitations. Finally, conclusions and future work are discussed in Section VI.

II. BACKGROUND

The University Hospital of North Norway (UNN) plans to replace some of the outpatient consultations with real-time telemedicine consultations. In May 2011, the management at UNN made a decision to invest in videoconferencing equipment at scale to provide specialist services to patients at local health centres and GP-clinics in the region. A committee report from 2011 estimated that 7000 patient consultations annually could be handled by video-consultations saving both hospital visits and travel costs (unpublished but available from the author on request). The implementation has been postponed awaiting further investigation into conditions for and potential consequences of a large scale videoconferencing network.

The reason for the videoconferencing initiative seems to be twofold: First, it has been recognised that high quality services for patients cannot be provided by one health care discipline alone or by one single sector. The new health care reform; the Coordination Reform is one initiative to ensure high quality services across sectors and between health care levels [10]. Using videoconferencing can contribute to more personalised and integrated care pathways: it will give the patients the opportunity to get treatment locally; they might avoid burdensome travels; and this might improve the quality of care through a better coordinated health service delivery. Second, the management at UNN wants to reduce the costs by reducing hospitalisation and outpatient visits and save travel costs (the health authorities cover travel costs in Norway).

A. Clinical videoconferencing

The use of videoconferencing to examine and treat patients over a distance can be used in most medical specialities and settings [2, 11]. In a remote specialist consultation, the patient, usually accompanied by a health care worker, meets the specialist in real time via videoconferencing. These latter types of telemedicine consultations have for example been used in psychiatry [12-14], dermatology [15, 16], oncology [17], to support renal dialysis [18], cardiology [19], in diabetes, asthma, epilepsy [20, 21] and lifestyle group counselling [22]. There now exists a range of evidence supporting that videoconferencing for a variety of conditions produce similar health outcomes to treatment delivered in-person [11, 23, 24]. However, there exists no robust evidence that remote video consultations is cost-effective compared to conventional health care delivery. Wade (2010) reviewed the literature of real-time video-communication and found it to be cost-effective for home care and access to on-call hospital specialists, it showed mixed results for rural service delivery, and it was not cost-effective for local delivery of services between hospitals and primary care [25]. It is, however, not realistic to make one general recommendation for cost-effectiveness across services and settings. The local context will decide important cost parameters, such as travel costs, the need for investment in infrastructure and technologies, and the opportunity costs of health professionals making it difficult to compare results across evaluations. Most reviewers, however, report that the evidence of cost effectiveness is scarce and more research on resource allocation and costs is still needed [26, 27].

B. Aim

In this project, we will use a combination of existing evidence found in the peer-reviewed literature and local data to build a decision model to analyse the economic impact of remote specialist consultations. The model will be used to structure and simulate patient pathways with, and without videoconferencing; to identify expected outcomes of different strategies; and, to explore the costs and benefits of different scenarios under different assumptions. The main aim is to assess the cost-effectiveness of remote specialist consultations using videoconferencing compared with usual care. This work is conducted in three related phases:

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1. Develop the structure of the cost-effectiveness model and identify key parameters relevant to the decision problem;
2. Identify local setting parameters such as medical field, investment and technical support costs, personnel- and travel costs.
3. Populate the cost-effectiveness model and analyse the economic impact of remote specialist consultations using videoconferencing in Northern Norway.

This paper describes the economic modelling study and reports on its first phase.

III. METHODS

Decision models provides a framework to draw costs and benefit data from a range of different sources together in a systematic way [5].

A. The Modelling Study

In this project, a decision model will be constructed to assess the cost-effectiveness of remote specialist consultations compared to usual care. In the model remote specialist consultation refers to situations in which the patients, usually accompanied by a health care worker at one location, consults with the specialist at the hospital using videoconferencing. Usual care refers to situations in which the patients see the specialist in a face-to-face consultation at the hospital. The model is populated with parameters collected from the peer-reviewed literature and with general cost parameters collected locally.

The primary outcome in the economic model is costs and quality adjusted life years (QALYs) in a cost per QALY ratio. If QALYs are not found in the literature, other effectiveness measures will be considered. If no effectiveness measure is found, episode of care (number of patients managed) will be used as an effectiveness measure and a net cost (or net benefit) per episode of care will be used as pathway outcome. Data on costs and effectiveness parameters are synthesised in a cost per unit of effect or a net costs to estimate average group values (cohort models). The model assesses short-term alternative branches or events defined as consultations. Another key model parameter of interest is the proportion of patients within each strategy or pathway. Probabilistic methods will be used both for estimation of expected outcomes and for sensitivity analysis. The evaluation will have a health provider perspective, that is, only include costs falling on the health care budget.

The data are collected in two steps. The first step is to conduct a systematic literature search to identify existing studies analysing effectiveness and cost-effectiveness of videoconferencing alongside randomised trials. The literature can provide information on structural assumption, parameter inputs, and areas of uncertainty. The second step is to collect local cost parameters. These include equipment costs, technical support costs, personnel costs, travel costs, and other health care costs from the health clinics involved. These will be collected from hospital departments, local health centres already using videoconferencing and regional health authorities.

This paper reports results from the first step: the literature search and structural model assumptions.

B. The systematic review

The systematic literature search has two main objectives; to collect information on a) previous cost-effectiveness analyses and decision modelling studies in real-time telemedicine studies; and, b) to collect data on structural assumptions, probabilities and clinical effectiveness in randomised controlled trials of using videoconferencing.

The search strategy included two main search terms:

1. Real-time telemedicine OR videoconferencing OR video-link OR video-communication OR videophones OR video-consultation OR hub and spoke OR remote teleconsultation OR real-time consultation AND
2. a) Economic modelling OR economic model OR decision model OR decision analytic model OR decision modelling OR cost-effectiveness OR cost-utility OR
   b) Randomised OR randomized

The following databases have been searched: PubMed, PsycINFO and ISI Web of Knowledge, CINAHL, Cost-Effectiveness Analysis Registry and the NHS Economic Evaluation Database (NHS-EED). Furthermore, reference lists in the retrieved articles and existing reviews have also been screened. Cost-Effectiveness Analysis Registry and the NHS Economic Evaluation Database (NHS-EED) were searched using videoconferencing, video-consultation or video-link as search words.

Only articles published in peer-reviewed journals were included. The search was limited to English language text and publication date from 1990 to 2013.

The articles relevant for this study cover remote specialist consultations using real-time audio and visual telemedicine technologies (videoconferencing) and only include aspects in which the patient is directly involved and present at the or GP office, local health centre or rural hospitals. Studies analysing video contact from home, store-and-forward transmissions of data, e-mail consultations or structured telephone support were excluded. We only included randomised trials to collect data on clinical process or patient flow through the health system, and clinical effectiveness of using videoconferencing.

Selection of relevant publications was based on information found in the abstracts. Full-text articles were retrieved when the abstract indicated a cost-effectiveness analysis and an assessment of effectiveness and patient flow through the health system. Full-text was also

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retrieved for closer inspection if the abstract did not provide clear indication of the content. Figure 1 shows a flow diagram mapping the number of studies identified, the number of studies included and excluded, and reasons for exclusions.

IV. RESULTS

The literature search identified 1265 records. These were found searching PubMed (n = 618), ISI Web of Knowledge (n = 532), CHINAL (n = 81) PsycINFO (n = 21) and NHS Economic Evaluation Database (NHS-EED) (n = 13). No articles were found searching the Cost-Effectiveness Analysis Registry. From these records, 46 full text articles were retrieved for further inspection. Two more articles were identified screening reference lists. Sixteen articles were selected for inclusion (see Figure 1).

The full text articles assessed were reviews, methodology papers, effectiveness and cost-effectiveness studies alongside randomised trials, case control studies and decision models. The decision modelling studies were analysing the use of videoconferencing in pulmonary care, stoke treatment and home visits for tuberculosis treatment [28-31].

A. *Inluded studies*

Sixteen articles were included in this review. Ten of these met all the inclusion criteria, that is, they reported results from randomised trails and included information on clinical process and patient flow of using videoconferencing in remote specialist consultations [32-41]. These articles form the basis for the model estimation in this study. Six other studies were also included. These were effectiveness or cost-effectiveness studies containing information on clinical process and effectiveness. These studies used case-crossover design [42-44], retrospective pre-post design [45] and two were models based on data from the literature [28, 46]. Reliable parameter data from these studies will also be used where parameter values are still lacking.

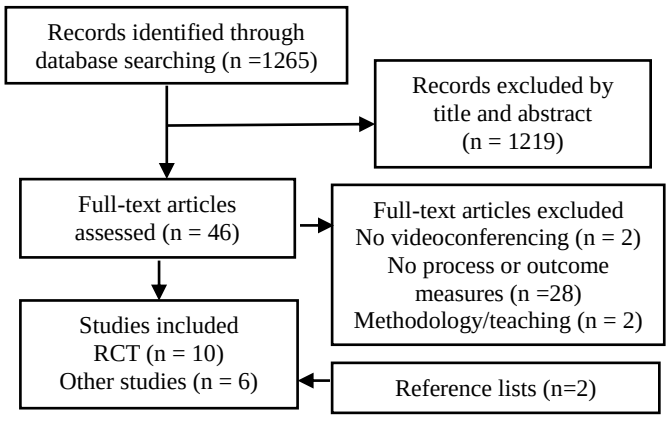

Figure 1. Flow diagram.

The included studies found data on the following parameters:

- The proportion of patients in which videoconferencing is a suitable and reliable option compared to face-to-face consultations.
- The proportion of patients in need of second consultation
- Outcome or clinical effectiveness
- Time use

B. *Model structure*

Data on patient management and patient flow found in the literature suggest that videoconferencing is acceptable for approximately 70 % of the patients [41, 42, 44]. This is supported by a review where it was reported that 70 % of the patients avoided travels [46].

Furthermore, the studies included reported an increased follow-up rate for patients seen by telemedicine [32, 34, 35]. For example one large scale telemedicine trial found that the follow-up visits for video consultations compared to usual care in general practice had an odds ratio of 1.52, 95% CI 1.27 to 1.82. [32].

The data suggest two possible models that describe the structural process of using video-consultations. The first model assumes a broad approach and includes all patients in the videoconferencing arm without any pre-selection. Figure 2, show this model populated with follow-up data from a large scale telemedicine trial by Wallace et al (2002) [32] as an example. Usual care refers to outpatient consultations. The second potential model assumes a screening process selecting the patients most suited for remote consultations beforehand. This might reduce the relative increase in follow-up visits for the remote arm. Figure 3 shows the model with pre-selection of patients.

Other parameters found in the included papers were:

- Effectiveness as number of patients managed times utility (preferences for videoconferencing compared to outpatient consultations). Utility was estimated by expert opinion (10 physicians) [28]
- Time use for the different alternatives [33]

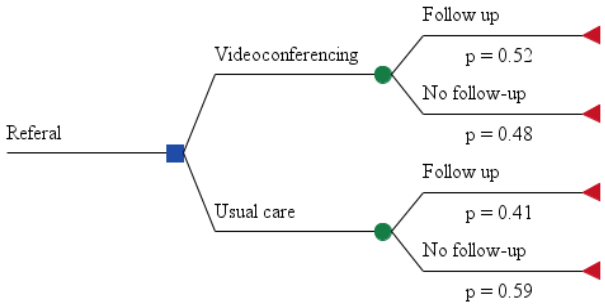

Figure 2. A decision model without pre-selection of patients populated with follow-up data from a large scale telemedicine trial as by Wallace et al (2002) [32] as an example.

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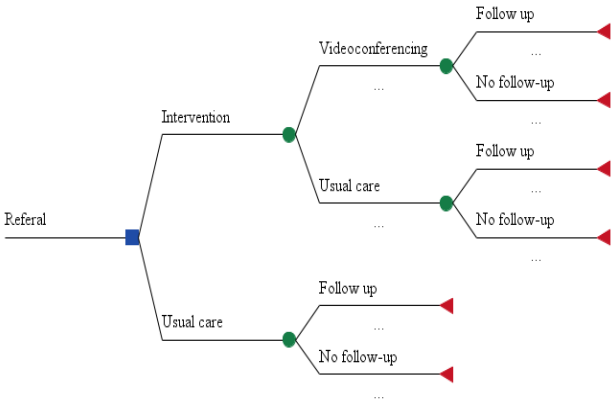

Figure 3. A model where the patients suited for videoconferencing has been pre-selected

None of the studies measured the clinical effectiveness of videoconferencing in QALYs.

V. DISCUSSION

The literature on telemedicine is extensive. A search in PubMed in November 2013 found over 16 000 papers on the topic. There is, however, a relatively small number of randomised trials in telemedicine research and even fewer analysing the effect of using videoconferencing in providing remote specialist consultations. A review from 2012 identified 141 randomised controlled trials in telemedicine [47]. These studies analysed interventions in chronic disease management and the majority analysed home monitoring and telephone support. Few studies looked into the use of videoconferencing. Recent telemedicine research seems to focus more on home based services using monitoring and telephone contact with less focus on remote specialist consultations using videoconferencing.

Only ten randomised trials met all the inclusion criteria and analysed the effect of remote specialist consultations. The clinical disciplines in the included articles were mental health, dermatology, orthopaedics, neurology and single studies with a mix of medical and surgical specialities. The studies varied in terms of sample size, outcome measures and contexts. All these studies included some evidence on patient management and the clinical process of using videoconferencing to examine and treat patients over a distance. Furthermore, we found that the increased offer of follow-up differed between specialities. It was highest in surgical specialities and neurology and lowest in mental health [32, 35, 38, 40]. This implies that the base model will have to include a specific patient group within one clinical discipline and not a general patient population.

We were not able to find any studies measuring clinical effectiveness in QALYs. One reason for this may be that using videoconferencing as a substitute for a face-to-face consultation have little or no effect on patient's health. The benefits for the patients are most likely the avoidance of burdensome travels. Since no QALYs were found, we will consider other preference measures identified from literature search. If the effectiveness measures is of low quality and cannot be used, a net cost per episode of care will represent the pathway outcome (assuming similar health outcomes).

The main purpose of this literature search was to identify randomised trials analysing the effect of remote specialist consultations. Consequently, the scope is therefore quite narrow. Furthermore, the fact that only articles written in English and published in peer-reviewed journals (to provide some basic quality control) were included is recognised as a limitation. The search strategy used might also have missed some evaluations. Remote specialist consultation is not easily defined. Some analysts might have used other terms and definitions to describe the provision of specialist treatment over a distance than the search terms used in this review.

The proposed model structures can be seen as hypothetical trial with two arms. In some context, the model might include a third arm in which the specialist travels to the remote health centres or clinics. None of the reviewed studies included this option. It will, however, be considered if a third arm is relevant in the areas selected for this study.

There is a number of valid concerns about using models to assess the economic consequences of an intervention [48]. The most important is the quality of the data used. The quality and validity of the results from modelling studies are not any better than the data used in the models. Telemedicine research has in general been criticised for being full of demonstration projects, anecdotal evidence and poor study design [49]. One way to ensure high quality data has been to limit the included studies to randomised trials. This strategy, however, produced few articles. To supplement the data six other studies were included.

VI. CONCLUSION AND FUTURE WORK

This paper has presented an economic modelling study, reported results from its first phase of collecting existing data from the literature and outlined potential model structures.

The next step is to develop the model, that is, to decide clinical field and primary care catchment area, to decide the final model structure and to organise and systematise the data on key input parameters and probabilities. Furthermore, we have to decide pathway outcome (cost per unit of effect or net costs). The model structure will also be adapted to local practices. Then local cost will be collect. The final step is to populate the model and analyse the cost-effectiveness of using videoconferencing for remote specialist consultations.

ACKNOWLEDGMENT

We thank the regional health authorities Helse Nord for funding this project.

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An eHealth Innovation Map for Small and Medium-sized Enterprises

Towards Feasible, yet Convincing, Evidence

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Abstract **- eHealth applications hold many promises, for instance to improve the quality of health care, to increase its accessibility, or to reduce its cost. Yet, many eHealth innovations never reach the stage where they get embedded into routine health care. This is due in part to a lack of evidence that these innovations indeed deliver what they promise. For small and medium-sized enterprises (SMEs) in particular, collecting convincing evidence for eHealth innovations proves to be a challenge as the available time, resources and expertise to do so are often limited. In response to this challenge, the research group *ICT Innovations in Health Care* at the Windesheim University of Applied Sciences initiated a joint research project, *Successful Entrepreneurship in eHealth*, with 28 eHealth SMEs, care providers, and other stakeholders in the Dutch health care system. The project's main result is an *eHealth innovation map*. This map consists of a diagram showing eHealth SMEs which parties in the Dutch health care system to involve, their roles and their mutual relations, their interests in eHealth innovation, and the kinds of evidence that may convince them of the added value of an eHealth innovation. A set of corresponding fact sheets was developed to provide eHealth SMEs with concise yet easily accessible information for choosing an appropriate "innovation route" and for determining what evidence to collect for relevant stakeholders. Preliminary findings show that the innovation map is indeed a useful instrument, and that the corresponding fact sheets manage to capture all the essential information needed to guide an eHealth SME along a chosen innovation route.**

Keywords - eHealth; innovation map; innovation route; evidence guidelines; health care system; stakeholder

I. INTRODUCTION

Getting an eHealth innovation embedded into routine health care often turns out to be a challenge, in particular for small and medium-sized enterprises (SMEs). Several causes can be identified, for instance a lack of a good underlying business model [1]. The research group *ICT Innovations in Health Care* at the Windesheim University of Applied Sciences (Zwolle, The Netherlands) has dedicated itself to study these issues and to support eHealth SMEs in overcoming them. Note that eHealth SMEs are defined here as small and medium sized enterprises offering eHealth products and services to patients, health care providers, and the general public. All SMEs participating in the project had less than 10 employees.

During a series of workshops organized by the research group, an inventory was made of the problems encountered when SMEs are trying to get eHealth innovations embedded into routine health care. Collecting *evidence* for an innovation came out first: to get their innovation accepted by patients and care providers, reimbursed by health insurance companies, endorsed by patient organizations, or approved by national health care authorities, innovators often need to show evidence for the innovation's effectiveness, for instance to improve treatment quality or reduce the cost of delivering health care.

For a typical eHealth SME it is often unclear what kind of evidence is expected and by whom, and according to which standards this evidence should be collected. In other cases, the standard may be clear (e.g., a randomized controlled trial) yet practically unfeasible for an SME due to a lack of available time, (financial) resources, or expertise.

Other researchers have also identified this barrier to eHealth implementation, although not specifically for SMEs. For instance, Mair et al. [2, 3] conclude in a meta-review of eHealth implementation studies that lack of validation and evaluation is frequently presented as a barrier to eHealth implementation: *"Without strong data demonstrating that a system works, improves standards of care, can be used efficiently and easily, and is cost-effective to implement, it is unlikely to win the confidence of policy makers and users."* [2, p. 23].

The project *Successful Entrepreneurship in eHealth* was initiated by the research group to address these challenges. The project constitutes a cooperation between 28 eHealth SMEs, health care providers, patient organizations, health insurance companies, and national health care authorities in The Netherlands. The project's aim is to establish guidelines for collecting evidence in such a way that (i) it is practically feasible for eHealth SMEs to do so and (ii) the resulting evidence is acceptable and potentially convincing for care providers, health insurers, or care authorities.

The project's main aim is to offer guidance to eHealth SMEs: which parties will need to be convinced of the

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effectiveness of an innovation, what evidence will be required, and how to collect this evidence in a feasible yet acceptable way.

The structure of the remainder of this paper is as follows. In Section II the approach followed will be introduced, including the four phases in which the project was structured. Next, Section III will discuss the main findings and lessons learned. Section IV describes the eHealth innovation map and the accompanying sets of fact sheets. Finally, Section V summarizes the main conclusions.

II. APPROACH

The project *Successful Entrepreneurship in eHealth* started at the beginning of 2012 and will conclude at the end of 2013. At the outset the project was structured into four phases; these phases are briefly outlined in this section. More details about the approach followed are given in [4] and [5].

A. Phase 1: Inventory

During this phase an inventory was made of generally recognized types of evidence. This was done by means of a literature review and a workshop with representatives of Dutch health care providers, insurers, patient organizations, and national health care authorities. Questions to be answered included: Which parties are involved when getting an eHealth innovation embedded in routine health care? What kind of evidence is generally needed, and how should it be collected? How do parties value various kinds of evidence? And what criteria are typically used?

B. Phase 2: Case studies

Whereas the analysis during the inventory phase was top-down, the analysis during the case studies was deliberately bottom-up – to involve the SMEs and to enrich the analysis with examples of concrete situations, dilemmas and obstacles encountered. Cases from the participating eHealth SMEs were subjected to a detailed study by means of in-depth, semi-structured interviews and an analysis of available documentation. Questions included: How are SMEs trying to get their innovations embedded into routine care? Which stakeholders do they identify and involve? What kinds of evidence do these stakeholders require? What evidence did the SMEs collect so far, and in what ways? How did stakeholders evaluate the evidence, against what criteria?

C. Phase 3: Guidelines and best practices

In this phase, the insights gained from the inventory and the case studies were combined. Best practices for embedding eHealth innovations in routine health care were identified, and guidelines for collecting required evidence were developed. Best practices and guidelines were then combined into a systematic approach for collecting evidence for eHealth innovations. To validate the newly developed approach it was applied and evaluated in a second series of case studies.

D. Phase 4: Consolidation and tool development

In this final project phase, the systematic approach described above was consolidated into an "eHealth innovation map". The map consists of a diagram showing eHealth SMEs which parties in the Dutch health care system to involve, their roles and their mutual relations, their interests in eHealth innovation, and the kinds of evidence that may convince them of the added value of an eHealth innovation. As part of the map, a set of corresponding fact sheets was developed to provide eHealth SMEs with concise yet easily accessible information for choosing one of four possible "innovation routes", and for determining what evidence to collect for relevant stakeholders encountered along each route. The map and fact sheets have been made available to a wide audience in The Netherlands, by means of a convenient booklet and a corresponding interactive web-based tool.

E. Ongoing dialogue

Next to the activities in the above four phases, regular project meetings were organized to stimulate an ongoing dialogue between the participating organizations. During these meetings, SMEs introduced their cases, representatives of health care organizations discussed procedures or criteria used to evaluate eHealth innovations, and the research team presented the project's latest results. To collect feedback from the project's participants, mini-workshops were organized to evaluate the usefulness and correctness of the developed tools, typically by applying them to cases at hand.

III. OVERVIEW OF FINDINGS

This section briefly highlights the main findings and lessons learned. A complete overview, including a detailed discussion of the case study results, is provided in [5].

A. Existing frameworks offer little guidance for SMEs

During the literature study more than a few reports and scientific papers offering proposals for eHealth evaluation frameworks were found, most of them containing guidelines for setting up a proper evaluation study, lists of outcome indicators and measures for various aspects of eHealth's impact, and descriptions of methods and instruments to collect data. Examples are the *National Telehealth Outcome Indicators Project* [6], *Model for the Assessment of Telemedicine Applications* [7], and *Guidelines for the Economic Evaluation of Health Technologies* [8]. However, these frameworks seem to be directed mostly at academic experts. The *Health Information Technology Evaluation Toolkit* [9] is one of the very few examples primarily aimed at the non-expert. It provides step-by-step guidance for project teams who are developing evaluation plans for health IT projects.

Although these frameworks indeed offer guidance with regard to setting up a proper study, none of the frameworks found provide the same kind of guidance with regard to identifying the various stakeholders involved in embedding an eHealth innovation into routine care, including their possible interests in the innovation, and subsequently the aim of an evaluation and the kinds of evidence that may be

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required. This is especially striking since researchers have argued for a contextualized approach in which all relevant stakeholders are actively involved in the definition of the outcome indicators that will be used [10, 11].

B. Stakeholders' views on evidence

During an expert session with representatives from health care providers, insurers, patient organizations, and national health care authorities, three dominant themes were recognized by the participants within the larger concept of evidence: *effectiveness* ("did health care get any better?"), *cost efficiency* ("did it get any cheaper?") and *labor savings* ("did it get any less labor intensive?"), including respective outcome indicators and methods. During the session it became clear that strong forms of evidence (obtained using, for instance, randomized controlled trials) are certainly not always necessary to facilitate the uptake of eHealth applications. The participants agreed that randomized controlled trials are not always useful, necessary, or practically feasible. Furthermore, care providers and health care insurers indicated that they will still rely on their own patient data to support any decisions they make about embedding eHealth applications.

National care authorities, on the other hand, held the view that eHealth applications typically only change the way in which health care is being delivered. As long as there are no indications that safety or clinical effectiveness are at stake, and within the limits defined by regulations governing the provision of health care, care providers and health care insurers are free to negotiate and decide about the use (and reimbursement) of eHealth applications.

C. Four "innovation routes" for eHealth innovations

One topic which arose very prominently during the same expert session, is that it is not straightforward which path an SME should follow within the Dutch care system to get an eHealth innovation embedded into routine care. In part this is due to the wide variety of applications that fall under the common denominator of eHealth, but it is also due to the complexity of the Dutch care system, which is highly regulated and in which various authorities and other parties each play a distinct role. An SME should consider very carefully which "innovation route" to follow, as the chosen route will determine which stakeholders to address and involve. Stakeholders will have their own roles, responsibilities and interests, and hence will need their own arguments to get convinced of an eHealth application's added value. It is, therefore, the chosen innovation route that determines the context in which evidence will be collected, the purpose for which it is collected, and the requirements that it should satisfy.

Based on the above findings, a review of online documentation pertaining to innovation in the Dutch health care system took place (e.g., [12-16]), and follow-up interviews with representatives of the participating health care organizations were organized. These efforts resulted in a comprehensive description of the Dutch health care system, including the roles of the parties involved, their interests in eHealth innovation, and criteria they use to evaluate eHealth innovations. Four main innovation routes were identified and described, including the specifics of each route and criteria for when to choose which route:

- The *consumer route* where an eHealth application is offered to and paid by patients/consumers. For example, a medical translation app that can be used when visiting a doctor abroad.
- The *provider route* where an application is offered to and paid by health care providers. For instance, an online treatment plan which allows clients to consult their plan and report about their progress.
- The *insurer route* where an application becomes part of an existing treatment that is offered by a care provider and reimbursed by a health insurance company. For example, a real-time medication monitoring service to improve the medication adherence of a diabetes patient. (In this case, the medication is the existing treatment and real-time monitoring becomes part of it.)
- The *government route* where an application leads to a new treatment not yet offered by care providers or reimbursed by health insurance companies, and where health care authorities need to decide whether it should be admitted to publicly insured care. Here, an example might be the introduction of telemonitoring of epilepsy patients in the home environment, to respond quickly in the event of a major seizure.

D. The paths followed by eHealth SMEs

During the case studies phase, eight cases submitted by seven SMEs were selected for in-depth, semi-structured interviews. During each interview, the path followed by the SME to get its eHealth innovation embedded into routine care was reconstructed. Particular attention was paid to the stakeholders that had been identified and involved, and (if applicable) the evidence that had been collected. Where available, underlying documentation was used to analyze the collected evidence, in particular the outcome indicators and methodology used, the conclusions drawn, and, if applicable, how these conclusions were translated into a business case for stakeholders.

A detailed discussion of the case study results is outside the scope of this paper. We briefly summarize a few highlights here, more details are reported in [5].

- Entrepreneurs with little or no experience in the health care sector often had difficulties in identifying a successful innovation route. The paths they followed were frequently based on trial and error, during which they steadily built up a better understanding of how the health care system works.
- The role of health insurance companies in the health care system, their interests in health care innovations, and the criteria by which they evaluate eHealth innovations were often unclear to SMEs.
- SMEs tended to involve health insurance companies too early, when strong support among care providers, endorsements from patient organizations,

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or approvals from professional associations were still lacking. Insurance companies, on the other hand, used these as principal criteria for the selection of promising innovations.

- Health care providers and health insurance companies often had partly conflicting interests, making it difficult to come up with a business case which was compelling to both parties at the same time.
- Within the "insurer route", clinical trials were often essential to build up evidence for an innovation's effectiveness. SMEs lacked the expertise and financial resources to carry out a proper trial, forcing them to involve experts and to find sponsoring. Furthermore, it was not always clear exactly what evidence was required.
- In cases where evidence had been collected in trials, this had been done using randomized controlled trials – the "golden standard" [17]. These trials were designed and performed by academic experts. These experts assumed responsibility for deciding which evidence was to be collected and how this should be done. However, it remained unclear to which extent external stakeholders had been consulted before these choices were made.
- The results from a trial had sometimes been developed into a business case for stakeholders. One case was especially illustrative: the effect that was found on an intermediary outcome measure used in the trial was first translated into an effect on a relevant end measure (a reduction in health related costs) using the results of a systematic review found in the scientific literature. This was then translated into a reduction in insurance claims for a health insurance company, based on the results of an internal study performed by the insurer. In this way, the clinical trial could focus on an intermediary outcome measure where effects could be measured on a much shorter time scale.

Judging from the cases under study, it was clear that decision makers (for instance in health insurance companies, but also in other stakeholders) should be more closely involved when an evaluation is being planned. In this way, the criteria that play a role in the decision process can be clarified early on, when they can still be taken into account in the development of evaluation plans or business cases, or in the design of clinical trials.

E. The criteria used by the insurance company

In the Dutch health care system, the insurance company often plays a crucial role in the reimbursement of eHealth based care. Based on three cases that were monitored closely during the project, it became clear that three criteria are essential for the insurer: (i) is there sufficient support for the innovation among care providers (for instance, does it address any evident needs or demands), (ii) does the innovation fit into existing health care processes, and (iii) will it be able to substitute for existing forms of care. Other important criteria were: (iv) is the innovation fully developed, (v) is it fully interoperable with existing systems

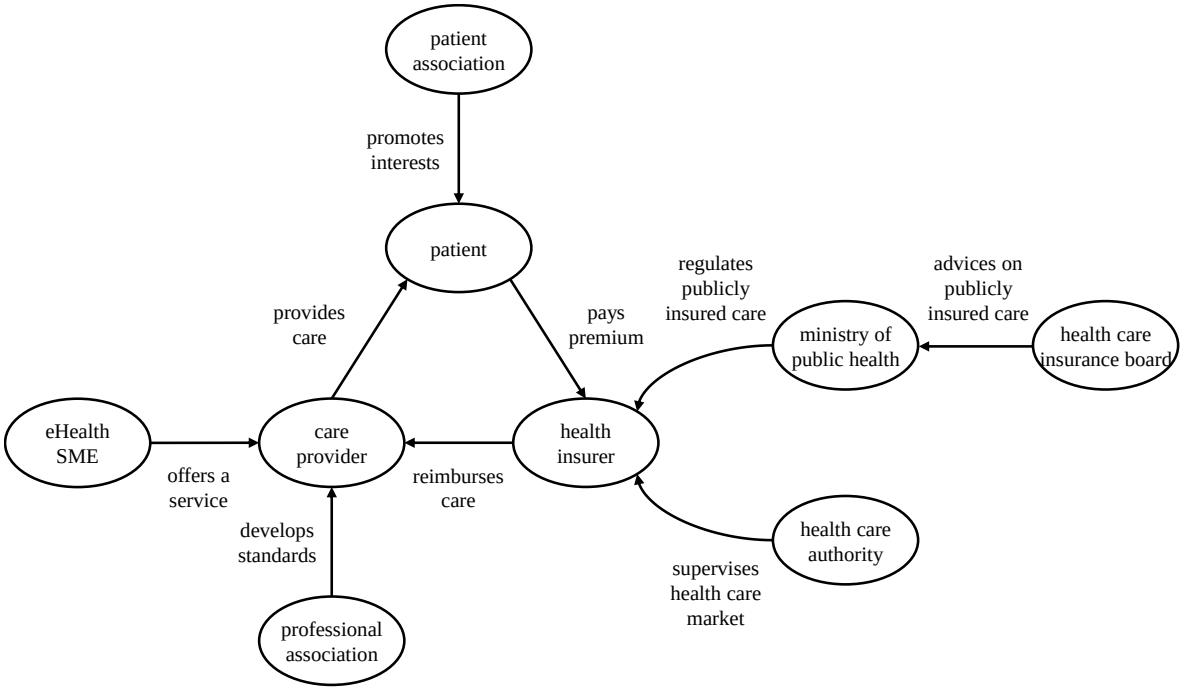

Figure 1: Elementary version of the eHealth innovation map, showing the main parties in the Dutch health care system. Each of these parties and their interests in eHealth innovations are further described in accompanying fact sheets.

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(for instance, systems in use by general practitioners), and (vi) is the potential for a nationwide adoption clear.

The criteria used by the insurer seem to be driven by a concern to identify early on which innovations will most likely be successfully implemented. However, the principal criterion is cost reduction by means of substitution: an eHealth innovation should either lead to the replacement of an existing form of care by a more cost efficient one; or, by being more effective, it should contribute to a reduced health care consumption in the near future. To convincingly show this to the health insurer, a detailed quantitative business case is often required.

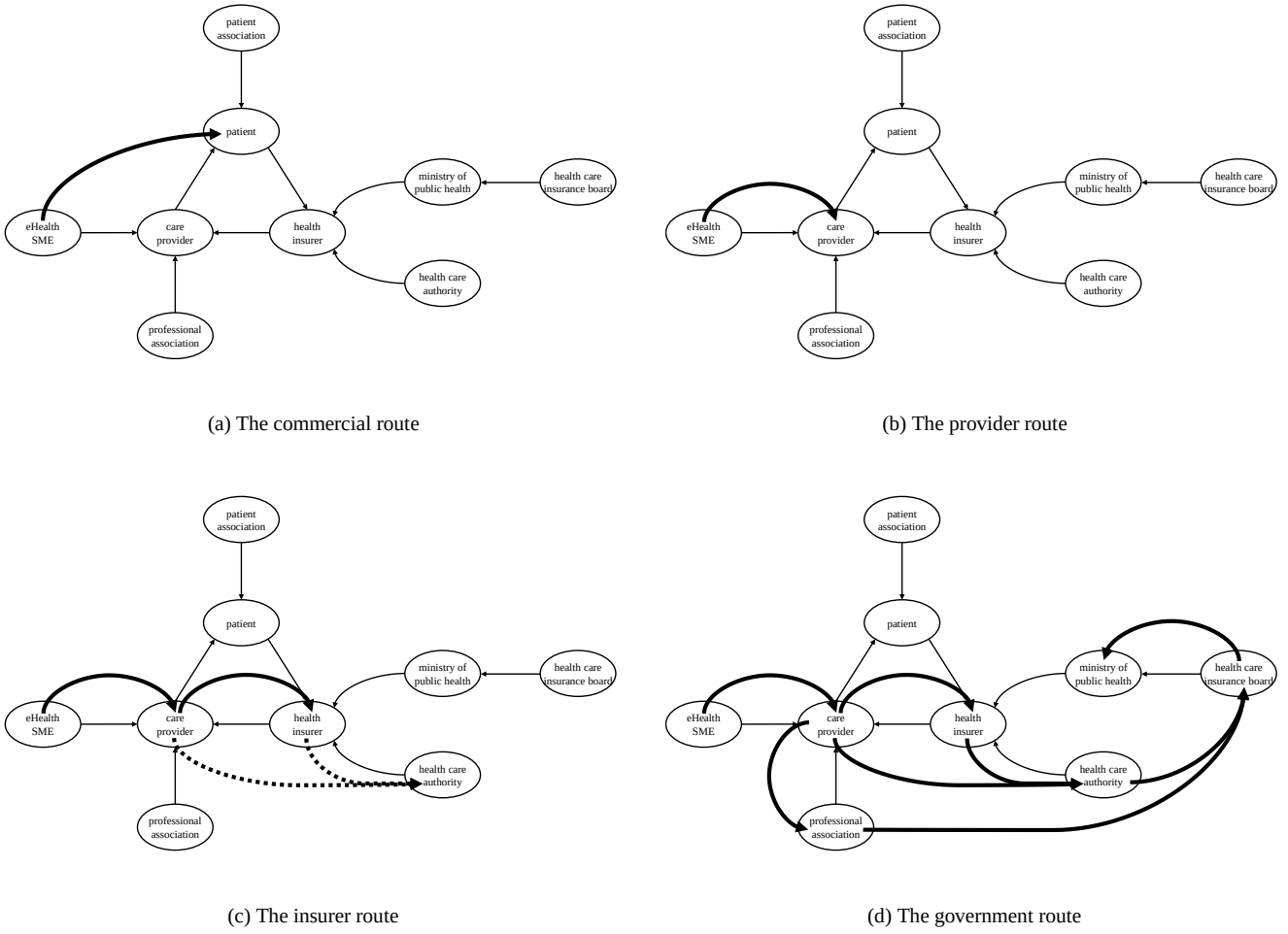
IV. FROM FINDINGS TO GUIDELINES

During the inventory and case study phases of the project it had become clear that, when evaluation plans or clinical trials are being planned, relevant stakeholders should be identified and their interests taken into account. This is especially important because, ultimately, the evidence that is collected will be constituting the foundation beneath a business case in which all relevant stakeholders and their interests are accounted for. Preferably, principal stakeholders should be involved as early as possible, and the required evidence defined and collected in a cooperative effort.

To facilitate this, eHealth SMEs required a "map": to find the most promising innovation routes within the Dutch care system, and to identify relevant stakeholders and their interests. The creation of such a map, including a set of corresponding "fact sheets" (detailed yet concise and accessible information on innovation routes, relevant stakeholders and their interests, and types of evidence required) became the project's highest priority.

A. The eHealth innovation map

The starting point when developing the innovation map was that it should provide concise yet accessible information for SMEs on (i) the Dutch health care system, (ii) the roles of the main parties within it, (iii) the interests these parties have in eHealth innovations, and (iv) examples of applicable evidence to convince them. Furthermore, the map should visualize the four innovation routes and so facilitate the identification of relevant stakeholders. The map should



(a) The commercial route

(b) The provider route

(c) The insurer route

(d) The government route

Figure 2: Thematic versions of the innovation map showing the four innovation routes. Thick arrows represent subsequent steps that should be undertaken by the SME or other involved stakeholders. Each version is accompanied by a descriptive fact sheet.

provide only an overview; detailed information with guidelines and best practices had to be provided in sets of accompanying fact sheets (of one page each): a set on the innovation routes, a set on the stakeholders involved, and a set on applicable evidence. The following paragraphs briefly discuss each of these elements.

1) The innovation map

Figure 1 shows the innovation map in its elementary version, displaying only the main parties in the Dutch health care system and the relations among them. Care has been taken to streamline the map without oversimplifying it. Three thematic versions of the innovation map (not shown here) display additional information: one shows the various stakeholders within each party, one the interests that stakeholders may have in eHealth innovations, and one the kinds of evidence (or other applicable forms of proof) that may be used to convince them. Furthermore, there are four thematic versions displaying the identified innovation routes; these versions are shown in Figure 2. Each version is accompanied by a brief description of what is shown. In this way, SMEs are provided with "at a glance" information which acts as an index to the accompanying sets of fact sheets.

2) Fact sheets on stakeholders

Each party is described in more detail in its own fact sheet. These fact sheets contain concise information on (i) the role of this party in the health care system, (ii) relevant stakeholders within this party that may play a role in decision making, (iii) their interest (or interests) in eHealth innovations, and (iv) general guidelines on how (and by what means) this party can be convinced. Table 1 shows a representative example of a stakeholder fact sheet, in this case about the insurer.

3) Fact sheets on innovation routes

The four innovation routes are also described in their own set of fact sheets. These fact sheets contain information on (i) situations where a particular route is applicable, (ii) matters to take into account when following a route, (iii) special circumstances or regulations that may apply, (iv) the main stakeholders that need to be involved, and (v) the main pitfalls. Table 2 shows a representative example of an innovation route fact sheet, i.e., the insurer route.

4) Fact sheets on evidence

The third set of fact sheets concerns the evidence that

TABLE 1: EXAMPLE OF A STAKEHOLDER FACT SHEET. THIS ONE DISCUSSES THE INSURER. OTHERS DISCUSS THE CARE PROVIDER, THE PATIENT, THE PATIENT ASSOCIATION, THE PROFESSIONAL ASSOCIATION, AND THE GOVERNMENT ORGANIZATIONS. (TRANSLATED FROM DUTCH; REFERENCES TO SOURCES IN THE ORIGINAL TEXT HAVE BEEN OMITTED FOR READABILITY.)

Fact sheet health care insurer

Role

The health care insurer is the party reimbursing the care being provided to patients with the eHealth application. Keep in mind that there will be various stakeholders within the insurer, all with particular interests with regard to the eHealth application:

- The innovation department, where potentially interesting eHealth applications are selected and evaluated.
- The investment fund, which backs the development of eHealth applications financially.
- The purchasing department, which negotiates with care providers and purchases large quantities of health care (as efficiently as possible). Therefore, the role of eHealth applications it often limited.
- The commercial department, which sets up additional insurance packages for private parties and collective insurances for organizations and which sees eHealth as a distinguishing feature.

Keep in mind that any enthusiasm in the innovation department is not necessarily shared by the other stakeholders!

Interests

As far as health care insurers are concerned, what is most important is high-quality care at low cost, which translates into the following demands being made regarding eHealth applications:

- The application needs to have sufficient support among care providers and patients (through co-creation).
- The application must deliver health care gains (better quality care or higher quality of life).
- The application has to reduce health care costs (through increased independence on the part of the patient or reduced burden on the health care provider).
- The application has to lead to substitution (no extra care but substitution of existing care).
- The application has to lead to reduced health-related absence (prevention or quicker recovery).
- The application has to be in line with national agreements and purchasing policies.

Health care insurers do business with care providers, who they see as interlocutor, which means it is important to make sure that the application is suggested to the health care insurer by an enthusiastic care provider (rather than by the entrepreneur).

Persuasion

Health care insurers have medical advisers who will assess the added value of an application on the basis of their expertise. Generally speaking, they will demand to see a business case, based on financial estimates and supported by research results (for instance a clinical trial or pilot project).

A business case can be created in stages, for instance by translating the effects that have been detected in a pilot study into financial consequences for the health care insurer. Always determine the design of a pilot study or clinical trial (what is being measured, and how) together with the care provider and health care insurer.

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will be required to convince the main stakeholders along each of the four innovation routes. The information provided in these fact sheets is necessarily generic; details on exactly which evidence to collect will depend on the specific situation (e.g., the type of eHealth application, where it is being used and to what effect, and the specific interests of relevant stakeholders). The fact sheets therefore contain (i) a concise description of the kinds of effects that need to be demonstrated for the main stakeholders, (ii) examples of the kinds of evidence that may be applicable, (iii) a few generic guidelines and best practices on how to collect evidence, and (iv) references to relevant sources of information, such as the frameworks discussed earlier in Section III.A. Table 3 shows a representative example of an evidence fact sheet, i.e., evidence for the insurer route.

B. Validation of the innovation map

Validation of the eHealth innovation map and the corresponding fact sheets has been performed along four different lines. First, experts from the participating health care providers, patient associations, and government organizations have been asked to carefully check the map and the fact sheets for correctness and completeness of the provided information. Several corrections and suggestions have been made by them, which have subsequently been incorporated into the materials.

Second, the usability and usefulness of the map and fact sheets have been evaluated with representatives from eHealth SMEs. This has been done during a series of workshops both within the project (as part of the regular project meetings) and outside of the project (e.g., at national and regional eHealth-related conferences and symposia). In these workshops the eHealth innovation map was applied to a range of different cases at hand (usually provided by workshop participants) and evaluation happened afterwards by means of questionnaires and discussions with participants. In this way, a substantial amount of valuable feedback was collected and used to improve the materials.

Third, validation of the map is currently being performed by means of "action research", where the research team is getting actively involved in a few selected cases with the aim to evaluate and extend the current insights.

Fourth, a number of successful cases are currently being

TABLE 2: EXAMPLE OF AN INNOVATION ROUTE FACT SHEET. THIS ONE DISCUSSES THE INSURER ROUTE. OTHERS DISCUSS THE COMMERCIAL ROUTE, THE PROVIDER ROUTE, AND THE GOVERNMENT ROUTE. (TRANSLATED FROM DUTCH; REFERENCES TO SOURCES IN THE ORIGINAL TEXT HAVE BEEN OMITTED FOR READABILITY.)

Fact sheet insurer route

When does this route apply?
An eHealth application is integrated into care that is already being provided or reimbursed. The application does not alter the care being provided, only the form in which it is delivered. As a result, for example, the care becomes more accessible or it can be provided more efficiently.

Examples
- An online nutrition diary that is used as part of diet advice by a dietician and promotes the patient's self-management.
- A pillbox that alerts patients when they forget to take their medication. This takes place on doctor's order and promotes patient discipline.

Points of interest
Make sure there is sufficient support! It is important for care providers, patients and patient organizations to be enthusiastic about the application, which is why it is crucial to involve them at an early stage in the development (co-creation). The specialists' professional association plays an important role in nationwide up-scaling, because they determine the guidelines for good and safe care.

If an application leads to cheaper or less labor-intensive care, while the quality of the provided care remains the same at least, this is interesting for the care provider and it may not be necessary to involve the insurer. If, on the other hand, the application makes the care being provided more expensive, it has to be demonstrated that the quality of the care has improved and a larger support base is needed. Do not approach the insurer yourself, but let the enthusiastic care provider do the negotiations.

As far as insurers are concerned, it is crucial for the application to lead to a replacement of existing care (for instance through substitution or self-management) and, ultimately, to a reduction in reimbursements. It is important to demonstrate this in a detailed business case.

Special details
If an application does not match the existing care descriptions defined by the Dutch Healthcare Authority (for example due to restrictions in the description or rate), the care provider and insurer together can submit an application at the Dutch Healthcare Authority. The Dutch Healthcare Authority can modify an existing care description or create a temporary one, giving the application time to "prove" itself.

The main stakeholders
- Care provider and professional association
- Patients and patient association
- Care insurer
- Dutch Healthcare Authority (if a care description needs to be modified or a temporary one created)

Pitfalls
Creating insufficient support (among patients, care providers, patient associations and professional associations). Approaching the insurer yourself without the backing of at least one care provider. Not paying attention to the substitution of the existing care.

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analyzed by means of desk research and interviews with parties involved, to assess the innovation routes that have been followed and the evidence that has been collected.

Overall, the consulted experts and participating SMEs had very favorable remarks. Judging from the feedback that was given, the innovation map does indeed manage to provide a concise and accessible overview of the various ways in which eHealth innovations can be embedded in routine health care. At the time of writing there is a strong interest in the map. It has, for instance, been made accessible to a large audience via the website of the Netherlands Organization for Health Research and Development [14] and a well-known website maintained by a joint initiative of four government organizations (the Dutch Healthcare Insurance Board, the Dutch Healthcare Authority, the Ministry of Health, Welfare and Sports, and the Netherlands Organization for Health Research and Development) [15].

The preliminary findings from the third and fourth lines (action research and analysis of successful cases) also provide support for the conclusion that the innovation map is a useful instrument, and that the corresponding fact sheets manage to capture all the essential information needed to guide an SME along a chosen innovation route.

C. Consolidation and tool development

The last phase of the project, consolidation and tool development, is currently nearing completion. Based on the eHealth innovation map a workshop protocol has been developed, and currently the innovation map and the fact sheets are being incorporated into an interactive, web-based tool [18]. The workshop protocol and the web-based tool both provide guidance to SMEs in finding a promising innovation route, in identifying relevant stakeholders to involve, and in determining which evidence they may require.

Last, the project's results are being documented in an accessible and illustrated booklet for SMEs. The booklet covers all the information contained within the innovation

TABLE 3: EXAMPLE OF AN EVIDENCE FACT SHEET. THIS ONE DISCUSSES EVIDENCE FOR THE INSURER ROUTE. OTHERS DISCUSS EVIDENCE FOR THE COMMERCIAL ROUTE, THE PROVIDER ROUTE, AND THE GOVERNMENT ROUTE. (TRANSLATED FROM DUTCH; REFERENCES TO SOURCES IN THE ORIGINAL TEXT HAVE BEEN OMITTED FOR READABILITY.)

Fact sheet evidence within the insurer route

What needs to be demonstrated?
A business case needs to be developed in which the interests of the care provider (see the provider route) and the health insurer are combined. Ultimately, health care insurers want to see a reduction in health care costs (through substitution or self-management), but they also focus on support among providers, scalability and compatibility with existing care processes. See the ZonMw website for a list of relevant criteria.

Which evidence is suitable?
Demonstrating a reduction in health care costs can be done in two ways:

1. By replacing expensive forms of care by less expensive ones ("substitution"). This leads to "definite", short-term cost reductions. Make clear to the insurer how the current care process will change and how this will lead to labor savings, process optimization, or lower costs. Pay attention to the aspects that will be included in the business case, and how this will be measured in a pilot or trial. Insurers will want to know how substitution is actually accomplished.
2. More effective care will lead to a reduction in care consumption in the long term, but the cost reduction is surrounded by uncertainty. Note that insurers will want to see a return on investment within three years. Reduced health care consumption will need to be demonstrated with methodologically sound research, for instance using this three-stage process: (1) a clinical trial aimed at measuring a process measure or intermediary measure, (2) translation of the effects found on the process or intermediary measure into an effect on a relevant end measure, based on the best available scientific evidence on the relation between these two, (3) calculation of the potential cost reduction based on insurer data. The Achmea Health Database is a good source of information to do this.

Some eHealth applications may be attractive for health insurer for commercial or marketing purposes (e.g., to attract or maintain subscribers). In such cases, contact the commercial department, which is responsible for additional insurances for consumers and collective insurances for organizations. In the latter case, it should be clear how the application can lead to fitter employees or reduced sick leave.

Things to keep in mind:

- In the case of improved efficiency, there has to be a clear (clinically relevant) improvement, which has to be demonstrated through scientifically sound research.
- Be careful about making assumptions, for instance in translating an intermediary measure (for instance, medication adherence) to an end measure (reduction or delay of complications). Do not add assumptions to assumptions.
- "Pick your battle": using a certain application may prove more beneficial with some syndromes compared to others. Think about this carefully.
- "Hard" data (which can be determined objectively) have more weight than "soft" data (opinions or experiences of patients and other people involved), no matter how they are collected. "Hard" data can also be obtained through routine registrations of care suppliers.

Important:

- Discuss as early as possible with the insurer and the care provider what evidence will be required.
- Involve important stakeholders, such as decision-makers, when working out the appropriate research approach.
- Consult experts when methodologically strong research is needed, but keep stakeholders involved.

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map and the fact sheets, such as the descriptions of the main parties in the Dutch health care system, the identified innovation routes, the interests of various parties in eHealth innovations, and various kinds of evidence that may be required. It is hoped that in this way, the project's results will be well consolidated and accessible for all interested eHealth SMEs in The Netherlands.

V. CONCLUDING REMARKS

The main conclusion to be drawn from the research presented here, is that evidence constitutes the foundation underneath a business case in which all relevant stakeholders and their interests are accounted for. Preferably, principal stakeholders should be involved as early as possible when planning an evaluation study or a (clinical) trial. In this way, the criteria that will play a role later on in the decision process can be clarified early on, when they can still be taken into account.

This insight has become the corner stone of the approach developed in the project "Successful Entrepreneurship in eHealth". Following this approach, the chosen innovation route, the identified stakeholders, and their interests in the eHealth innovation at hand eventually determine which kinds of evidence will be needed and how they should be collected. The developed eHealth innovation map, the workshop protocol, and the web-based tool were all developed to provide guidance to eHealth SMEs, allowing them to make better, more informed decisions. The design, implementation and analysis of clinical trials will nevertheless remain the domain of academic experts or highly trained staff members working at care providers; the level of expertise that is required makes this simply unavoidable.

With regard to the usefulness of the results in countries outside The Netherlands, the question arises how unique the Dutch situation really is. In other words, can the eHealth innovation map be generalized to other countries? When an early concept of the innovation map was presented at an international eHealth conference [4] it seemed from the responses given by the international audience that certain basic principles, such as the roles and interests of the care provider and the insurer, are certainly generalizable. Other aspects, such as the government legislation pertaining to the health care system, will vary. Nevertheless, judging by this first impression it seems that the proposed approach may be fruitful for parties in other countries as well.

ACKNOWLEDGMENT

The authors wish to thank Stichting Innovatie Alliantie for financially supporting the project *Successful Entrepreneurship in eHealth*. Furthermore, they would like to thank the eHealth SMEs and all other organizations who participated in the project: Achmea divisie Zorg en Gezondheid, ActiZ, Be4Care, BeagleBoxx, Bonstato, College voor Zorgverzekeringen, Consuming Knowledge, DiaDerma, Dutch IT Consultants, Eusamed, Evalan, EvoCare, Focus Cura, Health Valley, Installatie Techniek Masseling, Isala Klinieken, MS Nederland, Nederlandse Zorgautoriteit, Novay, Nederlandse Patiënten Consumenten Federatie, Nederlandse Vereniging voor eHealth, SalesSpirit, SymaX, Syntens, Valetudo Interpres, Vos Projectadvies Gezondheidszorg, VRC Telecom, and Zorgverzekeraar VGZ.

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Assembling Goal Attainment and Collaboration

Videoconference in Clinical Practice

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Abstract - **Videoconferencing (VC) for clinical work at scale is underway at the University Hospital of North Norway (UNN) as a strategy to support the goals of integrated and coordinated care pathways and reduce secondary health care costs. A research project: "Modelling Videoconference Collaboration" was designed to investigate financial and social aspects following this development. The project primarily looks at collaboration between clinicians. This paper reports on the sociological aspects of the project where the overall objective is to explore emerging new models for clinical VC collaboration and analyze specified mechanisms involved in optimizing the potential of the service. In the paper I report results on the question: what theoretical resources are useful for addressing processes towards goal attainment and VC practices of collaboration? Based upon a review of scientific publications, policy documents and theoretical work, a summary of experiences with VC use in Norway is presented to identify results on goal attainment and collaboration practices. International findings are also briefly considered. Complexities concerning influences and goals were identified. This result is used to introduce and discuss theoretical approaches, arriving at the concept of assemblage for addressing complexity. Arguing for the use of this concept, the paper concludes with operational questions for further empirical exploration and analyses.**

Keywords-video-conference; goal attainment; clinical practice; collaboration and integration of care; theoretical resources

I. INTRODUCTION

Videoconferencing (VC) for clinical work as part of telemedicine services has been used at the University Hospital of North Norway (UNN) for approximately 25 years [1]. During the last 5 years, measures to develop VC use at scale have been taken on as a strategy both to support the goals of more integrated and coordinated care pathways and reduce secondary health care costs [2].

The research project: "Modelling Videoconference Collaboration", ongoing 2013 and 2014, is designed to investigate processes and outcomes through multi-methodological approaches, including quantitative and qualitative methods. The overall objectives are to explore emerging new models for clinical VC collaboration and to analyze active mechanisms involved in optimizing the potential of the service, that is: the process of goal attainment. One half of the project addresses economic models and the other, which this paper derives from, examines socio-material models.

In sociology, determining theoretical positions and resources normally form large portions of projects. Basic assumptions, research questions, analytical approaches and concepts are considered to be intertwined and parts of the production of results. Therefore, the first aim was to determine theoretical resources and specify analytical concepts. In the paper I present and discuss responses to the question: What theoretical resources are useful for addressing processes towards goal attainment and VC practices of collaboration?

The resources are to be used for investigations and analyses of active mechanisms involved in goal attainment and collaborative processes, and to conceptualize socio-material models of optimization of potential. This aim will involve empirical studies of ways collaboration and integration of care are co-produced, and made viable and sustainable in specific practices where videoconference is used.

The paper is organized as follows: First, a section on methods and data for the theoretical considerations in this paper is presented. The following results section includes a presentation of published material on videoconferences, use, plans and anticipations in Norway, focusing on goal attainment and collaboration. Considering the results, theoretical approaches are then presented. I propose a concept of assemblages as a response to the findings of complexity of influences and goals in the research literature and documents. The discussion section addresses two questions: 1) how can goal attainment using information and communication technologies (ICTs) in health care be addressed? And 2) how can collaboration and integration of

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care be addressed? The paper concludes with questions and hypotheses for future work as well as data sources for the analyses of mechanisms and models for goal attainment, including collaboration.

II. METHODS AND DATA

The methods and data sources used for the sociological project reported here are as follows.

- Addressing Norwegian experiences, documents from the Regional Authorities of Helse Nord on videoconference use and priorities from 2005 were studied.
- A literature search was performed through Google Scholar using the terms "videoconference in clinical practice in Norway" and "videoconference use at UNN". Selection criteria were peer reviewed international publications reporting experiences from utilization of telemedicine including VC, dating from 2005 onwards. Papers with a focus on priorities, goal attainment and collaboration were included. Full text papers were retrieved and studied.
- Recent Norwegian government documents on health care reforms were studied, focusing on integration, collaboration and use of ICT's in health care.
- Peer reviewed scientific papers commenting on recent Norwegian reforms were studied.
- A literature search using PubMed was performed with the search term: "systematic review of use of videoconference in clinical practice". Reviews addressing videoconference, collaboration and goal attainment were selected, retrieved and studied.
- The main focus in this paper is on developing theoretical resources and concepts. A selection of work on processes of utilization, collaboration and governing of ICT's in innovation within the body of complexity studies was considered. This selection was substantiated through relevance for the subject area under study as argued in the paper.

III. RESULTS

In the results section, I present videoconference, its use in Norway, plans and assumptions as well as published results on goal attainment and collaboration.

A. Video conference definition and use

Although, in simple terms telemedicine refers to the delivery of medical and health services at a distance, there is no single or uniform telemedicine application. Telemedicine pertains to a dimension of distance that is bridged with the help of communications technologies, from Plain Old Telephone System (POTS) to satellite communications, ICT and networking technologies, such as the Internet, and the Global System for Mobile Communications (GSM) [3].

Video conference includes different technologies [4-6] making it a tool for collaboration between colleagues, education and remote patient consultation. Videoconference for clinical use is a synchronous service, indicating discussion of clinical questions with real time use of text, images, and video of the patient or wherever the patient may be present. The project I report on has its main focus on collegial collaboration. VC has undergone vast development, and today mobile units may be utilized by doctors for collegial discussion along with traditional VC studios or lecture halls equipped with large screens. The videoconference concept itself might be under pressure as technologies and use situations evolve [4].

In late 2005, the Northern Norway Regional Health Authority requested an evaluation of all tested telemedicine services in northern Norway to clarify which were suitable for large scale implementation. They developed a priority list of medical specialties and topics.

The first tier priorities were teleradiology, digital communication and integration of patient records, and education. The second priorities were teledialysis, pre-hospital thrombolysis, telepsychiatry and teledermatology. The third priorities were pediatrics, district medical centers, tele-ophthalmology and tele-otorhinolaryngology. VC was one type of service discussed.

In 2011, a report on the use and potential for videoconferencing in Helse Nord was commissioned as an internal report. The report concluded that there is great potential for the scale and nature of videoconferencing to increase. The recommendations were on pragmatic and operational levels and included the establishment of a new in-house organization to lead future videoconferencing, probably requiring specific expertise and resources to be bought in from outside companies. Rejuvenating the infrastructure, providing a well-resourced Service and Support Centre and increasing future involvement of clinical staff at UNN was also proposed. Strategic support at senior level in the University Hospital was also considered essential if the vision of future widespread use of videoconferencing for health care was to be realized.

Two different kinds of clinical videoconference were described as possible concerning inpatients and outpatients. Examples of the former include staff consultations about patients who have been discharged from the main hospitals to the regional and local levels. Following discharge, hospital staff could carry out regular case conferences with local staff to ensure proper follow-up. This does not take place on any scale at present; however, some outpatient video consultation already does take place including activity in dermatology, orthopedics and surgery, especially with stoma.

The report described considerable potential in outpatient follow-up by videoconference. For example, there were approximately 115,000 outpatient visits to the UNN per year. By supposing that one-quarter were from remote areas where videoconferencing would be preferable to travel, and

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that one-quarter of these appointments were suitable for videoconferencing (e.g. follow-up or "outpatient control"), this would represent an additional 7000 conferences per year, i.e. this would double the present number of videoconferences, and would increase the number of patient consultations by about ten times. Considering the latter as a hypothetical statement, I will address experiences from Norway when it comes to optimizing potentials next. Are operational and pragmatic strategies considered successful?

B. Goal attainment: experiences

Three papers have commented directly on different conditions for goal attainment understood as increased use of ICT's in health care for Norwegian services.

In psychiatry for instance, videoconferencing was mostly used for meetings, supervision and lectures, and to a lesser degree clinically with the patient present. Lack of videoconferencing equipment in collaborating institutions was identified as an inhibiting factor in use. A gap between the potential of videoconferencing and its actual utilization in Norway's mental health sector was described [7].

One paper accentuated user support, training, research potential, financial incentives and interactions between clinicians and ICT personnel as important factors in motivating health-care personnel to use telemedicine [8].

In another paper, factors for successful implementation were: usability, user participation, adequacy of training, potential for research, stated requirements for Mean Time Between Failures (MTBF) and communication between ICT personnel and clinicians [1].

C. Collaboration

Motivation and good communicative interaction between ICT personnel and clinicians were among the identified heterogeneous conditions for use. The Norwegian health care system is considered well-organized within its two main sectors; primary health and long-term care on one hand, and hospitals and specialist services on the other. However, the relationship between them lacks mediating structures. In 2003, the work of a governmental committee on collaboration was commented upon by Romøren et al [9]. The committee was described as having a sharp eye for the power game between primary and secondary health care, with the latter as the stronger. Their report argued for equalization as an important prerequisite for developing sound collaboration and coordination, and against primary economic or organizational reforms as effective means to optimize potentials in co-ordination and collaboration.

The new health care reform, the Coordination Reform, is one initiative to ensure high quality services across sectors and between health care levels [2]. The Coordination Reform represents a shift in perspective away from the operational to the administrative level and appeals to the need for economic or organizational reforms in order to foster collaboration and quality. The reform also represents a shift towards a focus on collective goal attainment, for instance via care pathways, as opposed to internal goal attainment for specific sections or institutions of health care.

In sum, goals of collaboration between the different sectors of health care, including strategies ranging from technological, operational, administrative, economic and organizational reforms were described, as well as challenges thereof. Active mechanisms for collaboration between different professionals and institutions will be further explored and conceptualized in the remaining phases of the project.

Collaboration between colleagues within the same profession and institution could prove to be parts of another conceptual model. Since the 1960s, substantial development in the uses of video-conferencing (VC) among medical personnel has been reported, including surgeons who have adopted the technology [10]. VC is widely used for telementoring surgical procedures and in trauma and emergency medicine. VC is also used by multidisciplinary teams and for the follow-up of patients after surgery. VC is considered a common clinical tool for surgeons, providing a great opportunity to alter surgical practice and to offer patients the best expertise despite especially great distances in rural areas.

A systematic review of inter professional collaboration (IPC) in health care reported that videoconferencing compared to audio conferencing in multidisciplinary case conferences showed mixed results. More rigorous, cluster randomized studies with an explicit focus on IPC and its measurement, were suggested to provide better evidence of the impact of practice-based IPC interventions on professional practice and healthcare outcomes. Studies should include qualitative methods to provide insight into how the interventions affect collaboration and how improved collaboration contributes to changes in outcomes [11].

IV. DISCUSSION

1) How can goal attainment, using ICTs in health care be addressed? 2) How can collaboration and integration of care be addressed? As evident, the three papers discussing goal attainment consider use of telemedicine as a success in itself, and the authors discuss conditions for obtaining more use. Use is a necessary condition for goal attainment. Taken together, coordination, collaboration, ICTs, economic incentives, power relations, organizational reforms and motivation were suggested as influencing use and goal attainment. These are highly heterogeneous influences.

In addition, collaboration and coordination seem to be considered both conditions for use and as parts of the goal. The impression from publications is that goal attainment and collaboration is intertwined, dependent parts of a complex array of factors, actors and relations, ranging from micro processes to overall political and economic decisions. In the next section theoretical resources are proposed and

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discussed for approaching and making sense of such complex arrays of factors influencing use of VC in health care and better collaboration for goal attainment. For this purpose, the concept of assemblage is explored after a short introduction to basic assumptions about ICTs and goal attainment within different theoretical perspectives.

A. *Basic assumptions in the studied literature: ICTs and goal attainment*

"Integrated care" and "improved patient pathways" are two main goals set by political priority through the Coordination Reform. These goals include operational, technological, organizational and economic regulations to foster collaboration and integration. Videoconference in different technological versions is one of the tools considered.

How clinical VC can contribute or be a means to achieve the goals involves complex processes. Processes of use, innovation and improvement have been considered with different basic assumptions of the roles and power of ICTs, their protocols and software standards:

- Information and communication technologies have become considered an institution into themselves by producing cognitive, normative and regulative effects in specific domains [12]. This view is stemming from Roger's ideas about diffusion of innovations first published in the 1960's [13]. This is a determinist view of technologies.
- Information and communication technologies have conversely been considered as both used and produced through and by the meaning that actors attribute to them in daily practices [14]. These are the social constructivist views, also pointing to individual actors or groups of actors and their motivations for use.
- Information and communication technologies have also been considered tools used by authorities or industry for governing behavior and institutions [15]. These are the instrumentalist views of ICTs.

B. *Assemblages*

In the papers reporting experiences and the policy documents referred to above, ICTs are considered with partly contradictory assumptions according to the perspectives outlined above. According to the policy documents, they are described as one of many factors instrumentally influencing goals, as having inherent regulatory effects and as strategic instruments. A body of research different from the determinist, social constructivist and instrumentalist views, has developed a terminology to address such complexity.

Some main characteristics from this body of research are described below, and their relevance for the empirical study to follow will then be discussed.

In this body of research, ICTs are described as one influence in heterogeneous and dynamic assemblages stretching from micro to macro, gaining power to influence goal attainment in ever changing constellations. Power is considered to be an empirical question in such assemblages, resulting from ongoing transparent negotiations, subtle power games and/or material, mental or scientific resource allocation [16-19].

Assemblages comprise in various mixes and connections a plethora of actors such as professionals, political authorities, technical agencies, bureaucratic organizations, ICT providers, service firms, regulatory bodies, software engineering companies, and research centers, together with the technical, functional and normative components with which they run their transactions. In different and unpredictable manners, these influence the faith of goals. All these actors are subject to being strengthened, disappearing or changing due to the processes.

An assemblage constitutes a loosely structured, ever evolving ecology of heterogeneous elements where boundaries and linkages among administrative bodies cannot be unequivocally fixed, tending to shift and drift in time. Assemblages are always ad hoc, thereby needing constant re-conceptualization. What seems to emerge as a distinctive feature of this institutional ecology is that coordination and execution of tasks are equally dependent on formal, normatively-based authority structures and on functional linkages and communication standards and protocols. The overall functioning of assemblages and the viability of the ecology itself are based as much on communications and functional relations as authority and norms [16].

The regulatory and enforcement capabilities are thus considered to be equally embodied in formal laws and regulations, and into technical standards and devices brought about by the technology, while the share of the latter pair is constantly growing. The combination of technical standards and software codes with bureaucratic procedures and legal codes give rise to novel institutional arrangements and practices, where ICTs increasingly provide the implicit context for the performance of practices and the overall operation of the administrative agencies. One of the visible consequences is that normativity gets dis-aggregated into specialized sub-assemblages [17]. Control over goal attainment is therefore an ongoing achievement and not predictable.

These assumptions and concepts are underlying an approach to scientific inquiry submerged under the broad category of complexity studies in which the ways individual roles, groups and organizations emerge, evolve and adapt to their environment are studied [20].

C. *Assemblages for studying goal attainment and collaboration for integration of care*

Formative and naturalistic methodologies that acknowledge telemedicine as an ongoing collaborative achievement have been recommended for assessments [21].

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Such approaches engage with stakeholders, including patients to produce and conceptualize new and effective telemedicine innovations. How may collaborating clinicians and patients be attended to in assemblages? Motivation was considered an important condition for use and this subject area will be addressed in the continued project. In recent social science work, the force and power of individual actors' evaluative relations to their daily activities has been highlighted [22]. Efforts to define and make professional excellence viable are considered to provide the emotional energy necessary to support and domesticate positive innovations. Involvement by clinical staff, motivation and communication were considered as important conditions for use, and are also inherent to the goal.

From the discussion above, the research questions for the second part of the sociological project can be more precisely defined: How are operational, technological, organizational and economic regulations, standards and reforms accommodated and reconfigured in daily collaboration using VC in clinical practices to obtain goals? How are improvements understood?

In order to analyze mechanisms, the project will more specifically consider:

- Which actors and factors make up the practices?
- What are their motives?
- What and who are enrolled?
- What and who are excluded and why?
- Which support is gained from what/who?
- What opposition is encountered from whom/what?
- What is changed and how are new models of VC collaboration enacted?
- How are goals of collaboration and integration of care understood and conceptualized?

By including accommodation in the question, the roles of individual actors, their knowledge and philosophies are acknowledged. These may vary between different actors and institutions. The research project therefore also addresses challenges and solutions of a philosophical character. Goals might be differently understood and the project will take into consideration different opinions and constructs.

A few challenges concerning collaboration and quality goals are briefly considered here. By looking at the combination of operational, strategic, motivational and material influences, the questions asked point to a deeper challenge for health care, for instance as described by Timmermans & Berg [23, 24]. They consider the dualism between what has been conceptualized as humanist care and technological standards as crucial to balance for health services to be sustainable

Such contradictions have been described between primary care and specialized services as units, and represent an underlying gap when it comes to collaboration. How may reconfiguration of standards in domestication processes reconcile the dualism between standardized care and humanized care? Contradictions in goals of humanizing care with the use of technologies, standards and structures in health care will be addressed in the project.

A second challenge that will be addressed within this perspective is discussed by Sayer [22]. Reconciling the dualism between normativity and values on one hand, and reason may prove to be an active mechanism for obtaining a viable practice of integration and collaboration.The project will address such underlying philosophical issues in case they are made relevant for understanding active mechanisms involved in goal attainment of collaboration and integration. The agency in everyday evaluative actions relevant to motivation for collaboration will be discussed additionally.

The question is to consider how collaboration and improved care pathways are performed and done beneficial to patients, nurses and doctors, taking all aspects, regulations, standards and reforms into consideration or not. The point is to explore how VC collaboration is performed in practices in ways that professionals and patients experience as good.

In addition this continued project will take into consideration deeper philosophical contradictions described by Timmermans and Berg, and Sayer, as they affect or are affected in efforts to obtain goals.

V. CONCLUSION AND FUTURE WORK

I conclude with questions, assumptions, hypotheses and data sources for future work. The questions that the discussion point to are: How are units and dualisms affected? What are the vital components of viable practices? My assumption is that units and dualisms will be reconciled in situations where collaboration is performed via VC in ways that professionals and patients experience as good. The hypothesis is that the approach of heterogeneous assemblages will sensitize such discussions.

For the empirical study to come, a wide range of data will be collected from observations, interviews, local data bases and existing literature. The project will provide models of conditions under which VC works and where goals are considered as obtained. The collaboration models will include knowledge about what clinical areas, under which circumstances, and for which patients VC works according to goals. In addition, it will include knowledge about how goals are obtained, that is: what are the active mechanisms involved? It is underscored that use in itself is not necessarily considered a success and the users' understanding of goal attainment will be described and discussed.

ACKNOWLEDGMENT

The project was funded by the North Norwegian Health Authorities 2013 and 2014.

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