Modelling Care Pathways in a Connected Health Setting

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Abstract. Connected Health involves the use of ICT to improve healthcare quality and outcomes. In a connected heath environment, stakeholders can struggle to make best use of this information coming from a variety of sources. Given this, we are investigating the challenge of how to use available information to make informed decisions about the care pathway which the patient should follow to ensure that prevention and treatment services are efficient and effective. In this paper, we outline our research into care pathway and information modelling in a Connected Health setting. The research is currently underway, and follows a series of stages using sources in industry and academia. In this paper, we present an overview of the project work packages including an explanation on how the different stages of the research form a continuum in which the developed models will be continually adjusted. We describe how empirical evidence will be used in the development of the models through following an evolutionary multi-method research approach.

1 The Challenge

The design, development and implementation of effective Healthcare Information Systems (HIS) is the pre-eminent concern of the Health Informatics discipline. In a report entitled *Crossing the Quality Chasm: A New Health System for the 21st Century*, the American Institute of Medicine recognises that "IT has enormous potential to improve the quality of healthcare" [1]. However, the same report recognized that the fulfilment of this potential represented an enormous, multifaceted challenge that tests both practitioners and the academic community.

An innovative approach to healthcare provision which has gained considerable interest in recent years is Connected Health. Connected Health encompasses terms such as wireless, digital, electronic, mobile, and tele-health and refers to a conceptual model for health management where devices, services or interventions are designed

around the patient's needs, and health related data is shared, in such a way that the patient can receive care in the most proactive and efficient manner possible [2]. The incentive behind Connected Health is to develop and deliver healthcare solutions that can increase quality of life and reduce the risk to patients while lowering the overall cost of care.

These Connected Health solutions require new clinical pathways and care delivery mechanisms. Clinical pathways, traditionally focused in primary and secondary care, are extending into the community. This repositioning of care provision will dramatically affect the volume and character of data that healthcare professional will have available to them. Care homes, hospices, hospitals and pharmacists will be interacting in a loosely connected, patient defined network. Patients will use mobile technology to record, store and transmit medical data. The difficulty healthcare professionals are faced with is how to use this data to make informed decisions about the care pathway which the patient should follow. Effective use of this data will require the creation of new and advanced health information systems that ensure that preventions and treatments are efficient and effective.

These health information systems "… *formally model guidelines, workflow or care pathways and provide support for clinical decisions that extend over time*" [3]. Health information systems are active, dynamic. And contain a large number of interacting components and subsystems. Artefacts in such a system include hardware components; actors such as healthcare professionals, IT experts and patients; and data that represents the state of the system at any moment in time.

The development of health information systems is supported by the use of models of both systems and processes [4]. These models support requirements capture and analysis. They are used to design, control and monitor system development and often serve a role in post-development validation and implementation.

The model of an information system is different and distinct from an instance of that information system. Similarly, the model of a health information system will be different and distinct from an instance of a health information system. A model will always be simpler and more abstract than an instantiated health information system. Crucially, models of workflows and care pathways must be understood by many different stakeholders, who may have different experiences, backgrounds and knowledge [5]. In the healthcare context, modelling is recognized as providing a unique challenge caused by factors such as the unpredictable and dynamic nature of workflows [6].

The research presented in this paper aims to model care pathways and information flow based on Connected Health solutions. Initially, we will focus on understanding and modelling the clinical preventions, treatments and control of dementia in the elderly. To do this, we will establish the information which comes from different healthcare professionals, systems and medical devices, how that information should be managed to provide effective and efficient care and the clinical pathways within which this information will be used. This will be carried out in conjunction with those healthcare professionals who are managing elderly patients, and will result in models and a software prototype for presenting these models which we will evaluate during the project. Therefore, the two aims of the research are as follows:

1. To unambiguously model the care pathways and information required by the variety of stakeholders in a health network.
2. To use software prototyping to develop an understanding how best these models can be presented to healthcare professionals.

In this paper we outline our planned programme of research for meeting these aims. The paper is organized as follows: Section 2 provides an overview of the research plan. Section 3 describes the work to date. Section 4 describes the planned work and key work packages to be delivered. Finally section 5 concludes our paper with a summary of the project.

2 Research Plan

Based on international best practice and input from local healthcare professionals, we will develop care pathways and information models that can be used by healthcare professionals in a Connected Health network, which will include home-care and hospitalization. We will develop models and software for the distribution and presentation of care pathways and information models throughout this Connected Health Network.

This research will be delivered across five work-packages:

- WP1 – Requirements Capture
- WP2 – Development and Modelling of Care pathways
- WP3 – Development and Modelling of Information Requirements
- WP4 – Prototype of Care pathways and Information Requirements
- WP5 - Evaluation of Information Utilization

The goal of our research is to present an evidence based care pathway for dementia which is disseminated to Connected Health stakeholders in a manner that informs and expedites effective decision making. With this in mind, we will describe each of the proposed work packages. As we have commenced WP1 we present how we are eliciting the requirements for a care pathway support system and our initial decisions on our modelling approach. Our future work discusses WP2, 3, 4 and 5 - how we will develop and evaluate a care pathway support system that will use the care pathway models.

3 Research to Date

3.1 WP1 - Requirements Capture

The purpose of this work-package is to identify the key requirements for the modelling of care pathways and information flow in the Connected Health network. We are answering the following question - “What are key requirements for representing care pathways and information flow?” These include the information, knowledge, clinical

and medical device requirements that are required. Defining the data that must be collected regarding individual patients, the aggregated sets of data which are required by healthcare professionals and other Connected Health partners, the use of medical devices in the care and support of the dementia patients and the pathway which is followed by health professionals as they carry out their jobs. In addition it is important to understand the requirements for out of bounds data which indicates the occurrence of exceptional events thus requiring immediate interventions.

To date, we have considered both the state-of-the-art in workflow modelling and expert knowledge from practitioners and academics. We are systematically identifying and analysing requirements from the literature. We are commencing a qualitative meta-synthesis which will be performed on studies published in English that addressed the modelling process and reported the exposition of a new methodology, model, system implementation, or system architecture. Thematic analysis will be used to capture the underlying 'requirement' themes.

We have developed an initial definition of the requirements based on which we conducted surveys among experts to assess the relevancy, completeness, and relative importance of our initial requirements. We prioritized and refined the requirements based on experts' opinion. We merged some requirements based on the experts' suggestions and rephrased some requirements to address misunderstandings and ambiguities found. Furthermore, when refining the requirements we took into account additional requirements suggested by the experts.

Using the identified requirements, we performed an evaluation of current modelling languages. A modelling language is any artificial language that can be used to express information or knowledge or systems in a structure that is defined by a consistent set of rules [7]. There is an enormous variety of modelling languages in existence.

Modelling languages can be graphical (e.g. UML [8]), textual (e.g. PML [9, 10]), mathematically based formal languages or a combination of these (e.g. Petri-Nets [11] or Little-Jil [12]). Modelling languages are designed in such a way as to balance a large number of competing attributes including, but not limited to, how easy they are to understand, how well they support the representation of a process and what kinds of different syntactic structures such as loops and conditional branching they support.

Different modelling languages balance these competing requirements in different ways, and the syntax of a modelling language will have a major impact on the models that are created with it Therefore, since the efficiency of any Connected Health solution is determined in part by the utility of the model, which is in turn partly determined by the choice of modelling language, it stands to reason that the choice of modelling language used is an important determinant of the eventual success or failure of a Connected Health solution.

Based on our evaluations, we have identified a 'best-fit' language that advocates the value of low-fidelity models for documenting and analysing knowledge-intensive work in health care setting [13]. A low fidelity model does not seek to capture every detail and nuance of a knowledge-intensive process; rather, it documents the major activities of a process, and the primary sequence in which they are performed. Coordination among concurrent activities performed by different actors is modelled as

resource flow: dependencies among coordinated activities are represented by the resources shared by concurrent activities.

4 Further Research being Undertaken

4.1 WP2 – Development and Modelling of Care pathways

We used previous experience in the development of a process reference model [14] to design a research method which will result in an empirically-grounded model of care pathways in dementia. An initial review of the relevant literature indicated that while high level descriptions of dementia care pathways are available there are few low-level pathway descriptions. Furthermore, no guidance is provided on how the pathway descriptions could be applied or tailored to specific setting. Documented pathways require customisation where the defined process needs to be specialised and a lower level frequently needs to be constructed in order to create a working model.

We will use a multi-method research design as advised in [15]. This is "the conduct of two or more research methods, each conducted rigorously and complete in itself, in one project" [16]. By using triangulation between methods and data, our research will allow more plausible interpretations to emerge.

According to [17] multi-method research may be conducted from a complementary or evolutionary perspective. In the development of our models, we will follow an evolutionary approach. We will undertake an initial exploratory study. We will gather qualitative data, exploring a wide range of topics. We will analyse the results, and use it to develop an initial pathway model. Using a variety of research methods, we will collect and analyse data, and update the model over three cycles. Our approach will be influenced by [18] and is focused on empirically grounded and valid process model construction. In an analogy with systems engineering, the overall construction process is based on a cyclic structure to allow for corrections to the model from preceding construction stages via feedback-loops. Although the stages are dealt with sequentially, they contain cyclic sub-stages. The research approach will be compatible with common suggestions for qualitative research designs in process models [18] and is presented in Figure 1.

Version one of the model will be developed through available literature and clinical guidelines. Version two will be based on ethnographically informed practitioner evidence. Key stakeholder activities will be observed and observations extracted. These observations will be used to design an interview protocol to be used during a series of semi-structured interviews. From these interviews, key concepts will be extracted combined to form a pathway model. Version three of the model will be based on process mining techniques as proposed by van der Aalst [19]. The goal of process mining is to use event data to extract process related information, e.g., to automatically discover a process model by observing events recorded by systems used throughout the Connected Health network. There have been several documented case studies [19] of the use of process mining techniques in clinical settings.

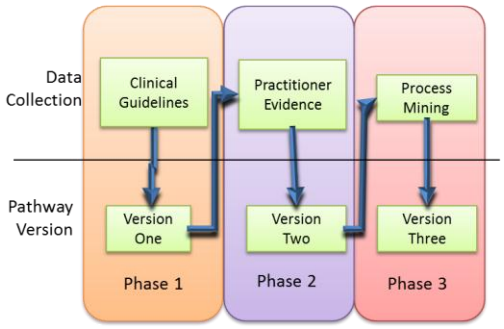

Fig. 1. Modelling phases

When developing the model, we will be identifying the key process indicators required to measure patient care and subsequent improvements, and will use these to develop data dashboards. These will be based on the dashboards which we are currently using within a local hospital. We will establish the key inputs, process and outputs required to ensure that medical devices and data from medical devices are used efficiently and effectively in these pathways.

From our past experience in developing and implementing H-QAP in a local hospital, we recognize that there is a need to "reverse engineer" the clinical process from a systems perspective. This gives us the opportunity to analyse where the efficiency points are, where the system fails, where system intervention is needed and where human contact from healthcare professionals is required. Using H-QAP will guide us in the identification of policies, procedures, protocols, and guidelines, key process indicators (KPI) and patient satisfaction ratings. These research stages will form a continuum in which the focus of the research, the model, is continually adjusted based on the results of the previous stage.

4.2 WP3 – Development and Modelling of Information Requirements

Using the information collected in WP1, a data dictionary will be developed which models the information requirements of the various stakeholders in the Connected Health network. Where required, techniques and algorithms to collate, compress and aggregate the data captured by the various Connected Health solutions will also be identified and defined. Models will be created which explicitly includes the information requirements of the various Connected Health stakeholders.

4.3 WP4 – Prototype

We will develop a system which will meet the requirements for a care pathway support system and which is more explanatory in nature than enforcing. Rather than prescribing a list of actions to be performed at each and every stage of the pathway, we will adopt a reactive approach, whereby a Connected Health stakeholder is provided with guidance only when they explicitly ask for it. The pathway support system is

'descriptive', in the sense that the stakeholder does not even need to inform the system about the activities he has performed while executing a pathway. Rather, the pathway enactment engine infers the state of the pathway by examining the state of products created or modified during the performance of the process's tasks. Then, if an actor requires guidance as to what tasks should (or may) be performed next, the system can use the inferred state to determine the next action to be taken, according to the underlying pathway model.

The prototype will gather information, where appropriate aggregate it, and provide targeted information to the various stakeholders in the Connected Health network in line with their information requirements defined previously. It will provide a support system for the care pathways that have been identified. We expect that it will support the decisions that a healthcare professional will make about a patient such as what clinical care is required, where this should be carried out (in the community or hospital), what medical devices can support this care and what data is required for this care to be carried out effectively. Healthcare professionals will be provided with dashboards which will aggregate data to measure their defined KPI, highlighting where problems and potential problems exist. It will also take into account software quality regulations commensurate with a research project [20]. We will develop this prototype to ensure that the information can be accessed on a wide variety of device's including, but not limited to desktop PC's, laptops, tablets and mobile phones.

4.4 WP5 - Evaluation of Information Utilization.

This task will focus on evaluating the impact of the optimized information and care pathways delivery to healthcare professionals. Using relevant evaluation frameworks, the overall effectiveness and efficiency of the software prototype will be evaluated. This work package will evaluate the utilization of the information collected and its effectiveness on the decisions which are being made in the prevention and treatment during the dementia care pathway. This task will focus particularly on ensuring that the information being captured and collated is valid, and that decisions being made are supporting the efficiency and effectiveness of the clinician. It will also examine the utilization of the information provided by the software system on clinical decision making, and look for changes in patient outcomes and care in terms of previously identified KPI.

Second, this task will focus on evaluating the effectiveness of the methods by which the data is presented to healthcare Professionals. In this task, experimental research will compare a variety of ways of presenting information to healthcare professionals, with a view to empirically identifying best practice for delivering information to healthcare professionals in a manner that aids decision making.

5 Conclusion

In response to a need for pathway support in Connected Health, the authors identified the following research objectives: First, to unambiguously model the care pathways

and information required by the variety of stakeholders in a health network. Second, to use software prototyping to develop an understanding how best this information can be presented to healthcare professionals.

By meeting these objectives, we hope to assist stakeholders in dementia care networks as to how to use available data to make informed decisions about the care pathway which the patient should follow to ensure that preventions and treatments are efficient and effective.

In this paper, we have documented our approach for the support of care pathways in Connected Health and the research design decisions made. For Connected Health to reach its potential there is a need to define and present evidence-based pathways and this research is a step in this direction. The plan we present is high level. Further research is needed to support the definition of what, when and how tasks are used for specific contexts, domains or organization in the Connected Health setting. It would also be interesting to consider a more rigorous information systems development approach which considers the interplay between various system stakeholders.

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