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Healthcare of the Future

Bridging the Information Gap

Editors: Thomas Bürkle
Michael Lehmann
Kerstin Denecke
Murat Sariyar
Serge Bignens
Erwin Zetz
Jürgen Holm

IOS Press

Imagining the healthcare of the future is an interesting exercise, and although nobody can predict precisely what systems might operate in ten year's time, the possibilities which already exist can give us a clue as to how healthcare may be managed by 2030.

This book presents papers from the conference *Healthcare of the Future*, held in Biel/Bienne, Switzerland, on 5 April 2019. The conference reflects some of the results of a two year multi-stakeholder Swiss research program in medical informatics. The research program, which began in 2016, saw 25 stakeholders cooperating for an integrated cross-sectoral treatment pathway with the goal of avoiding communication gaps and information loss among the different participants within the treatment process. The principal goals were to improve and accelerate healthcare processes and empower the patient to play an active and decisive role within their own care process. The project highlighted interaction between caregivers, patients and healthcare institutions based on modern information technology. Topics covered are divided into 4 sections: workflows in healthcare; how does eHealth change the care process; knowledge based IT support; and eHealth and the informed patient, and the book also includes the keynote conference speech on improving the hospital-patient relationship with digital communication.

The book will be of interest to all those involved in healthcare whose aim is to improve and accelerate healthcare processes and empower patients to play a more active and decisive role in their own care.

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HEALTHCARE OF THE FUTURE

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International health informatics is driven by developments in biomedical technologies and medical informatics research that are advancing in parallel and form one integrated world of information and communication media and result in massive amounts of health data. These components include genomics and precision medicine, machine learning, translational informatics, intelligent systems for clinicians and patients, mobile health applications, data-driven telecommunication and rehabilitative technology, sensors, intelligent home technology, EHR and patient-controlled data, and Internet of Things.

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Edited by

Thomas Bürkle

Bern University of Applied Sciences, Switzerland

Michael Lehmann

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Kerstin Denecke

Bern University of Applied Sciences, Switzerland

Murat Sariyar

Bern University of Applied Sciences, Switzerland

Serge Bignens

Bern University of Applied Sciences, Switzerland

Erwin Zetz

GS1 Switzerland

and

Jürgen Holm

Bern University of Applied Sciences, Switzerland

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Healthcare of the Future
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5 April 2019

Thomas BÜRKLE[a,1] Michael LEHMANN[a], Kerstin DENECKE[a],
Murat SARIYAR[a], Serge BIGNENS[a], Erwin ZETZ[b] and Jürgen HOLM[a]
[a] *Bern University of Applied Sciences, Biel, Switzerland*
[b] *GS1 Switzerland, Bern, Switzerland*

Healthcare in 2030?

Imagine you live in the year 2030. Global warming is still a big issue. You live in the suburbs of a big city because few people still live in rural areas. You commute to work by public transport. Occasionally you will use your electric car. In many Western countries the majority of baby boomers have already reached retirement age with almost a quarter of the population older than 65, so medical care is also a constant issue.

As a human being, you can still get sick. The many elderly people and a life expectancy of almost 90 years means that chronic diseases and dementia have increased despite medical progress. However, technological progress and prevention due to increased health literacy have led to less than expected increases in health care costs. Thanks to intelligent assistants, older people can live safely at home for longer in a more self-determined manner. In 2030, digital medical services are standard via the internet. Your GP advises you via telemedical services to fill in a digital questionnaire with your medical problems. If necessary, the intelligent house-doctor system transmits measured vital and behavioural data to the family doctor. Furthermore, he requests from your electronic health record the three-monthly follow-up of your personal wearable devices, which continuously monitor your blood pressure, pulse, oxygenation, blood glucose and activity levels. His information system post-processes this huge amount of data in real time to present a medical dashboard of your current condition to your doctor while you are still in the videoconference. With the help of this decision support system your GP can easily distinguish those problems which he can solve remotely from those where he really needs to see you. He can even inform your employer that you will be unable to work for some time. The GP information system calculates in real time a recommended therapy scheme including your personal genomic data to ensure compatibility. Your GP reviews this recommendation and sends a medication order directly to the pharmacy. Amazon delivers your medication within an hour to your home with its rapid drone services. At the same time, your health insurance automatically receives a digital invoice for the treatment.

[1] Corresponding Author Thomas Bürkle, Bern University of Applied Sciences, Quellgasse 21, CH2501 Biel/Bienne, Switzerland; e-mail: thomas.buerkle@bfh.ch.

Well, like the people reading Jules Verne's "Around the World in Eighty Days" [1] in 1873, we don't know which of these scenarios might become reality in 2030, 2050 or ever, but we certainly live in a time when ubiquitous IT provides us with computers in our pockets which are powerful enough to support photography, video and audio recording, video telephony and access to a wide variety of information worldwide – we call it a mobile phone. We have already reached the stage where personalised medicine can examine the individual conditions of patients to find the appropriate therapy for each person. Data mining and artificial intelligence promise to discover new ways of treating previously incurable diseases; something which recently prompted a politician to say that within 10 years we will have overcome cancer [2]. On the other hand, an ageing society and the loss of family ties confronts us with an increasing number of elderly and multi-morbid persons striving to live independently for as long as possible.

This is the setting for the 2019 conference *Healthcare of the Future*. The medical informatics conference is centred around emerging digital communication options and their influence on future medical treatment. It originates from a research project which started in 2012 [3] with a scenario similar to the beginning of this introduction. A clinical pathway was drawn up for the case of an elderly Swiss lady called Elisabeth Brönnimann-Bertholet, who is suffering from diabetes and hypertension, under the assumption that her progredient hip arthrosis now requires surgery (fig 1).

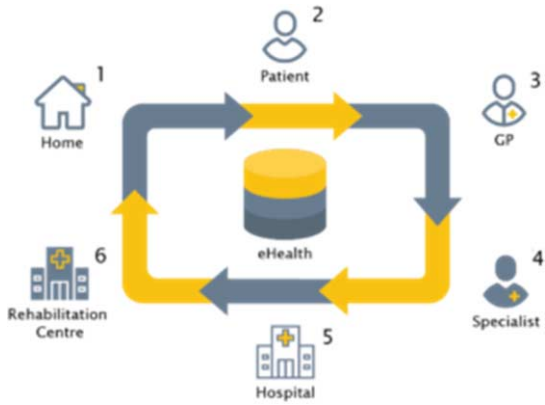

Figure 1. Cross institutional clinical pathway, starting with home care and disease prevention (1) to case history (2), diagnostics and referral (3), maybe indication for surgery (4), surgical intervention and postoperative treatment (5), and rehabilitation (6) before returning home again

In a visionary brainstorming process, Bern University of Applied Sciences BFH, the Swiss branch of the standardizing organization GS1 [4] and the umbrella association of the Swiss business sector 'Economiesuisse' [5] analysed the required medical and information processes and drafted an innovative cross-sectoral treatment pathway for Mrs. Brönnimann to obtain a total hip endoprosthesis (TEP). Communication within the pathway relied on emerging information technologies [3].

In the meantime, a new bachelor study programme for medical informatics has been founded [6], a department for medical informatics established, and an institute for medical informatics research constituted at the BFH. With this background, a larger second research project called "Hospital Of The Future Live" (SDZL) [3] began in 2016, with 25 partners including six Swiss hospitals, four major IT suppliers, IHE

Suisse, and eHealth Suisse: the coordinating body for the implementation of the Swiss electronic health record Electronic Patient Dossier (EPD) [7]. The goal of SDZL was to turn parts of the visionary scenario into a tangible reality – at least in the laboratory environment of BFH medical informatics. SDZL [3] had a multi-stakeholder driven approach. Project goals were set and continuously adjusted in five plenary meetings with all involved parties. The cross-sectorial treatment pathway for TEP was split into a total of 68 more or less atomic work packages at home and in the outpatient situation prior to hospitalisation, the inpatient rehabilitation sector and the return to the home situation. These work packages centred around communication-intensive tasks where either current shortcomings were found or potential for improvement was expected. Work packages were then combined into (often cross-sectorial) student projects. A detailed description of the process can be found in [3].

A good example is the electronic Medication Management Assistant eMMA. This is a laboratory prototype for an app on mobile devices designed to help patients take their medications regularly, and has the goal of improving drug therapy adherence. eMMA uses a Conversational User Interface CUI to remind the user to take their drugs. If the medication is not taken, eMMA asks for the reasons, just like relatives who chat with the elderly via SMS [8]. Primarily, this app is designed to support Elisabeth at home prior to her inpatient treatment and after her return from rehabilitation. In a future setting, however, it would also be linked to Elisabeth's inpatient treatment to convey the medication information to the hospital staff and to receive the newly updated medication scheme at discharge. The future Swiss EPD [9] could have an important role in these transitions.

The 2019 conference "Healthcare of the Future" is to some degree a result of these research projects. Our goal for the conference is to discuss advanced interaction based on modern information technology between nurses, caregivers, patients and healthcare institutions with other specialists in medical informatics in an international setting. We would like to demonstrate whether and how this interaction could improve and accelerate healthcare processes, and we would like to discuss the future role of the empowered patient within their own care process.

After a short presentation of the conference background the programme will start with the keynote

"Digital Patient Communication: Improving the Hospital-Patient Relationship". Three sessions in the scientific track deal with the topics

- Workflows in healthcare
- How does eHealth change the care process?
- Knowledge-based IT support

In parallel we will have young two researcher sessions under the topics

- eHealth and the informed patient
- Apps to support the patients and caregivers

Biel /Bienne 14 February 2019

The Programme Committee

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Digital Patient Communication: Improving the Hospital-Patient Relationship

Hans-Ulrich PROKOSCH[a,1], Christina SCHÜTTLER[a], Michaela SCHRAUDT[a], Matthias ÖFELEIN[a] and Christian MAIER[a]
[a] *Chair of Medical Informatics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany*

Abstract. Digitally engaging patients in their care processes was for many years limited to sharing care related documents (e.g. laboratory or radiology findings, discharge letters) with them through personal electronic health records. Newer concepts have led to the establishment of patient portals as patient frontends to a hospital´s electronic health record. Rarely however have complete patient pathways with pre-hospitalization, inpatient stay and post-hospitalization been evaluated to identify chains of communication processes involving clinical care scenarios, as well as subsequent home monitoring scenarios. Neither have such approaches been integrated with digital communication processes related to a patient´s engagement in medical research projects. In order to enhance hospital-patient relationships in a holistic manner, we hypothesize that an integrated environment (e.g. patient portal) supporting shared decision making and communication in a patient´s care situation and in the same time providing communication processes for patient research engagement will optimize the patient-hospital relationship and be supportive in binding a patient to this care providing institution.

Keywords. Electronic patient portal, digital patient communication

1. Introduction

„Citizens in Switzerland are digitally literate and use the possibilities of new technologies in an optimal way in order to care for their health. Health institutions and health care professionals participate in a digital network, exchange information along the care process digitally and can reuse once documented data for multiple purposes" This is the vision in the eHealth strategy Suisse 2.0 for the years 2018 to 2022 [1]. One of the five goals in this eHealth strategy claims that *„if patients can self-determined decide about the access to their health data and can themselves access their data whenever they want to, they can be more actively involved in the decision making process in terms of their health behaviour their health problems and their medical treatment. They thus strengthen their own health competency"*. One of the major tools for this digitalization process with strong patient involvement is the electronic patient dossier (EPD) [2, 3]. In Austria a similar personal electronic health record is currently being established, also as a means to „simplify the process of accessing one´s health records for patients and their doctors, as well as other health

[1] Corresponding Author, Hans-Ulrich Prokosch, Chair of Medical Informatics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Wetterkreuz 13, 91058 Erlangen, Germany; E-mail: Hans-Ulrich.Prokosch@fau.de.

care professionals at hospitals, care facilities and pharmacies“ [4]. Both system´s architecture is based on a distributed network of data repositories and registries according to the IHE XDS integration profile. In Germany the eHealth law has been published in December 2015 and defined an electronic patient record which should be useable by every patient with statutory health insurance latest in January 2021. In December 2018 a first specification of the respective applications has been released [5]. All such approaches however have their major focus on a *„Health Information Exchange (HIE), which allows health care professionals and patients to appropriately access and securely share a patient's medical information electronically"* [6].

The wording in the above definitions always depicts the sharing of health (care) related documents and a shared access to such patient information. Technically many of those personal electronic health records are based on IHE profiles such as IHE Cross Enterprise Document Sharing (XDS) and IHE Cross-Community Access (XCA). Rarely do the specifications of such personal electronic health records directly relate the technical process of „document sharing“ to real world clinical processes, especially to care process related communication processes between health care institutions and patients.

On the other side has the field of mHealth applications in recent years gained an enormous attention and data generation, e.g. based on miniature sensor technologies, directly by patients are meanwhile state of the art. The promotion of innovative mHealth applications (e.g. smart phone apps) will, in the context of the Swiss EPD play an important role for the increased patient involvement [1]. Last but not least, it has been mentioned in many scientific publications, especially coming from U.S. researchers, that the widespread electronic health record adoption has also led to an increasing interest to leverage patient portals to improve care [7].

Based on those current developments we will in the following propose digital patient communication processes, which aim at improving the hospital-patient relationship based on patient portals as entry points into a hospital´s electronic health record systems. The focus of such patient portals will however not only be on document sharing, but rather on efficient support for dedicated patient care and translational research processes with efficient integration of various types of mHealth applications.

2. Digital patient communication processes in patient care pathways

The typical non-emergency patient pathway of a patient for a planned inpatient stay starts with providing the patient with general information about the hospital itself, how to locate to the hospital (e.g. parking lot), especially to the patient admission area and with information how to find the clinic/ward. The patient may be additionally informed about particular preparations she would need to take care of before coming to the hospital. Traditionally such information is still send to a patient by postal mail.

In a modern innovative hospital with an electronic patient portal however, the first step involved in a first contact with the patient might be to ask her, if she would prefer to communicate electronically via the hospital´s patient portal, or if traditional surface mail or phone contacts would be her preferred communication channel. In the years to come we predict that a steadily increasing number of patients will prefer online communication and would be open to use a mobile phone app in order to securely communicate with their healthcare provider. According to the German internet usage statistics in 2018 the age group of over 70 was the one with the highest rate of

increased internet use at all, whereby close to 70% of the group 70 and older and 82% in the group 60-69 are internet users already in 2018 [8]. According to "We are social" more than two-thirds of the world's population now has a mobile smartphone. They describe, that it's increasingly easy for people to enjoy a rich internet experience wherever they are [9]. Thus, in less than five years we can expect that more than 90% of the patients will prefer a mobile online communication with their hospital.

Therefore hospitals in Europe should follow the example of many U.S. hospitals which have already implemented patient portals and are now in the phase of evaluating their patient portals' effectiveness [10]. Others are investigating the usage of patient portals for communication scenarios with patients with chronic diseases (e.g. diabetes patients [11] or lung cancer patients [12]). Especially such chronic patients with many hospital inpatient and outpatient contacts will preferably stay in contact with their care provider based on digital communication through a patient portal. Thus, we imagine, that in a typical pre patient admission communication in future a patient portal may not only provide the patient with information about his upcoming stay, but may also directly gather some patient history information in order to make the later history taking process in the hospital more efficient.

Following a patient´s pathway through the hospital we do already see investigations to also support hospitalized patients during their stay with inpatient portal functions directly at the bedside (e.g. [13,14]). After a patient´s discharge, monitoring the patient´s status electronically or supporting her in her control and self management (e.g. for diabetes patients) is already supported by numerous types of mobile smart phone applications [15]. Finally, many developments have already focused on continuous home based glucose monitoring [16], smart home-based health platform for behavioral monitoring and alteration of diabetes patients [17] or even sensor-based monitoring approaches with contact-lenses [18].

However, all such innovative new developments currently are singular standalone applications which are investigated in pilot implementations or early clinical trials. In a hospital the chance is currently high that different such mobile monitoring and patient communication technologies, applying sensor technologies and mobile applications, are investigated by different specialties for different disease scenarios. This illustrates the urgent need for a coherent platform approach, were a hospital defines a strategy on how to integrate the numerous pre-/post- and hospitalization scenarios for monitoring a patient´s status at home, but also continuously staying in touch with her and providing efficient, digital means for communication, into an EHR integrated patient portal. It further illustrates that improving the hospital-patient relationship can not just be solved by more or less static document exchange or sharing (e.g. via personal electronic patient health records), but requires a comprehensive understanding of complete patient processes in their pathway from a planned admission, through the inpatient phase and after the patient´s discharge. Especially for patients with chronic diseases such pathways typically repeat themselves continuously and dedicated communication processes through such a chain of hospital contacts should by established and digitally supported.

3. Digital patient communication processes for patient research engagement

Digital patient communication however shall not only be related to the patient care process. In recent years there is also a growing interest in engaging patients in

healthcare research [19, 20]. As illustrated by Hearld et al however, although it is promising that people are interested in being engaged in research, the results suggest that there is work to be done to raise awareness of these engagement opportunities [21]. While raising awareness to opportunities for patient research engagement is one challenge, obtaining a patient´s informed consent for the reuse of data, which are for example collected during their hospital care, for patient centered outcomes research and other types of real world data analysis is a further challenge. Large international data sharing and data reuse projects such as e.g. PCORNET [21,22] or OHDSI [24] are currently being followed by similar European initiatives, such as the German medical informatics initiative [24], the German biobank alliance [25] or the Swiss Personalized Health Network (SPHN) [26]. All such initiatives are currently working on creating (hopefully nationwide standardized) patient information folders to describe potential future use of data for research and healthcare in very general terms (modular broad consent) [27] and apply this for obtaining a patient´s informed consent.

In a best practice approach engaging patients in such types of research partnerships, obtaining their informed consent, but also providing them easy ways to also withdraw their consent again, shall also be accompanied by personalized information about the use of their data in respective research studies. Spencer and colleagues for example have explored patient perspectives on the use of anonymized health care data for research purposes and evaluated patient perceptions about an electronic system to enable and implement ongoing communication and collaboration between patients and researchers [28]. In their case, patients can digitally tailor preferences about whom they share their data with and can change their preferences reliably at any time. Furthermore they propose electronic systems which provide opportunities for informing patients about data recipients and the results of research to which their data have contributed. Rare disease researchers have, in the RUDY (Rare UK Diseases of bone, joints and blood vessels) study successfully pioneered an approach which applies a custom-developed electronic platform for such research oriented patient communication and where patients can additionally contribute information over time about their disease experience, lifestyle and clinical history [29].

In a comprehensive research infrastructure, such as the data integration centers, which shall be established as integrated parts of a hospital´s information system infrastructure in the German medical informatics initiative [24] many components need to be integrated for an efficient and data protected flow of data from the clinical environment to the respective research data repositories. In the MIRACUM consortium we build those data integration centers on the MIRACOLIX ecosystem, which amongst others comprises components for data pseudonymisation (ID-management), consent management and project proposal management [30]. The latter shall be applied for entering data usage requests for new research studies, support the internal review process of such a data request for obtaining the vote of the data access and usage committee, publishing data usage projects which have been initiated based on data from a respective MIRACUM site and finally tracking such projects for their research results.

In order to motivate the future engagement of patients in the medical informatics initiative research projects we propose to establish a patient portal in a respective university hospital as an entrance port towards the hospital´s EHR, but also to the integrated environment of the project proposal management and the consent management components of a data integration center. As a major component for the support of research oriented patient communication processes the portal should provide

means for accessing a multimedia (e.g. animated video) electronic patient information, a digital consent/withdrawal frontend, and, similarly to the RUDY portal, enable ongoing communication, information about data usage and collaboration between patients and researchers [29]. Additionally, the patient portal should contribute to patients providing information over time about their disease experience, lifestyle and clinical history.

4. Conclusion

In a society with more than 90 percent of people accessing the internet via their smartphone, where digitally booking one´s train-/flight ticket, making hotel reservations, ordering foot and participating in social media communities are common activities of daily living for almost everybody, hospitals can not ignore that traditional paper and postal mail communication will be outdated soon. Even though today still parts of the older patient generation may not be online yet, this can't be taken as an excuse for not planning ahead and at least visioning future hospital-patient communication scenarios, where the relationship between a patient and "her" hospital will strongly depend on the efficiency and ease of use for digitally communicating with their doctors and with the hospital administration. Communication however is always embedded in more complex scenarios and treatment pathways and is much more, than just exchanging documents. We are therefore convinced that innovative hospitals planning ahead for the future, will analyze and model their communication scenarios, especially related to patients with chronic diseases, will in parallel also design relevant research related communication scenarios and thus create a set of requirements for their future EHR integrated patient portal. In the years to come we need to see many more such pilot implementations. However, we also need to realize that hospital-patient communications are still a very new area and that not just the technology but rather the socio-technological changes associated with such new communication channels will be the most important challenges to master. Thus, evaluation research on the acceptance of such portals and the features which will really be accepted and used by patients will be important for their successful stepwise introduction.

5. Conflict of Interest

The authors declare that there is no conflict of interest.

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2. Workflows in Healthcare

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Cross-Institutional Pathway Guidance Chance or Extra Burden?

Thomas BÜRKLE[a,1] Michael LEHMANN[a], Jürgen HOLM[a], Murat SARIYAR[a], Erwin ZETZ[b] and Kerstin DENECKE[a]
[a] *Bern University of Applied Sciences, Biel, Switzerland*
[b] *GS1 Bern, Switzerland*

Abstract. In this paper, we examine requirements, show potential user interfaces and describe a prototypical development for a Pathway Navigator App that guides the patient through healthcare episodes. Our use case is a fictional patient requiring surgery for a hip total endoprosthesis. Fundamental is the provision of appointment information and the option to contact the healthcare provider for rescheduling. This implied an architecture which was more complicated than expected. We realized an HL7 interface for appointment data from hospital information systems; no comparable standard was found for GP IT systems. The future Swiss Electronic Patient Dossier could enhance the integration of the Path App within a broader health-IT ecosystem.

Keywords. Clinical pathway, app development, medical informatics

1. Introduction

Clinical pathways have been promoted for healthcare since considerable time [1-4]. *A clinical pathway is a document describing the common process of a multidisciplinary treatment for a particular type of patient* [1]. Pathways were promoted in Australia (Sydney) [1,2], particularly, as an answer for cost control in view of the impact of diagnoses related group reimbursement, which leads to reduced inpatient stay and mandates faster diagnostic and therapeutic workup of the patient. Most of these efforts, however, define clinical pathways within a single institution [2,3,4].

Patient care, however, is often not limited to one institution, but rather a combined cross-sectorial effort where many caregivers in inpatient and outpatient segments have to cooperate for an optimized treatment. Our idea within a research project was to improve co-operation by supporting streamlined workflows [5].

The "Patient Navigator App" was planned as a mobile application accompanying the patient through all parts of his/her outpatient and inpatient care and rehabilitation using the hip total endoprosthesis (TEP) as a use case. Here, we describe the development process and discuss the challenges in implementing such application into practice.

[1] Corresponding Author Thomas Bürkle, Bern University of Applied Sciences, Quellgasse 21, CH2501 Biel/Bienne, Switzerland; E-mail: Thomas.buerkle@bfh.ch.

2. Methods

The Patient Navigator App was an essential part within the Swiss research project "Hospital of the Future". This project consisted of several stages. The overall use case was a fictional elderly multi-morbid patient requiring hip surgery and implantation of a hip TEP for advanced arthrosis. The first project stage delivered a vision for a digitally enhanced future of the Swiss healthcare system. The goal was to develop prototypical IT applications to demonstrate parts of this visionary process. Twenty-five partners including six Swiss hospitals, four major IT suppliers and eHealth Suisse, the coordinating body for the implementation of the Swiss eHealth environment, co-operated as active stakeholders [5]. A set of atomic work packages were defined and combined in student activities supported by our stakeholders. Results were implemented as prototypes in our comprehensive medical laboratory environment. Specifically, the Patient Navigator App was developed in four consecutive student activities.

2.1. Medical informatics seminar – analysis of the problem

In a first step, the information regarding clinical pathways for hip TEP was collected from literature and in discussions with stakeholders. The students identified options where IT could help to save time and make information on the patient available. Further, similar applications available on the market were identified and a first system architecture with required interfaces to clinical systems was developed. In a survey among potential users of the patient navigator app, requirements with respect to the application's functionalities as well as desired design components were collected, using a paper-based mockup of the application. In addition, the general use of mobile devices among elderly patients was investigated in this survey.

2.2. Clinical Apps for tablets – definition of required functionality and app interface

"Clinical Applications for tablets" is a competitive teaching format [6] where different project teams deal with the same task. Their task was to develop a visualization of the appointment data and to define functionalities. Three project teams were established to construct a first prototype of a Patient Navigator App. The groups were free to decide their architectural approach, their programming environment and their user interface design. Two groups used the Vaadin framework [7] for app development, the third group opted for Gluon [8].

2.3. Living Case – prototype development

"Living Cases" are courses with the goal to develop prototypes of IT-application [6]. Two students realized a prototype of the Patient Navigator App, comprising an app frontend for the patient, a PathApp server [9], a web interface for healthcare professionals to support scheduling and rescheduling of appointments and a HL7 V2 interface for the exchange of appointment data. The PathApp server was implemented in Java Script in a NodeJS environment on top of a MySQL database with a REST-API for interaction. The web interface for use by healthcare professionals was programmed in the React JS framework [10] on Microsoft IIS. The app for the patient himself was implemented in React Native. The HL7 V2 interface was realized using the rimiti hl7 object parser [11].

3. Results

The different student activities resulted in a functional prototype of the Patient Navigator App that is able to retrieve appointment data and to visualize the treatment path for the patient.

3.1. Interfaces and requirements

The interface analysis revealed the requirement to connect the app to 1) information systems at the general practitioner (e.g. using the Swiss GP communication standard SMEEX [12]), 2) to hospital IT applications using e.g. HL7 V2 messages and 3) to IT systems of rehabilitation centers using CDA-CH format. Sequence diagrams were designed to define appropriate transmissions and updates of rescheduled appointment dates.

16 persons (9 female, 7 male) aged between 60 and 80 participated in the survey. Use of modern communication technologies was rather high among the participants: 14 out of 16 (88%) use a smartphone daily, 2 use it on a weekly basis. 3 persons (19%) use additionally a tablet PC on a daily basis. Another 4 persons (25%) use a tablet PC every week. Based on the paper-based mockup of the patient navigator app, half of the participants confirmed such app to be very useful or useful. Most participants (12 / 75%) desired an organizer function. Additionally, they asked for reminder functions and checklist functions.

3.2. Competitive Search for a User interfaces

The competitive task of interface design resulted in three clearly different solutions for the patient's user frontend (Fig1). Following the collected feedback from potential users, a schedule-like version was selected as the most promising design (see Fig. 1, middle). This appointment visualization is similar to the app of the Swiss railway SBB showing the route of the train together with the time of arrival in a timeline. Since this SBB app is often used by Swiss inhabitants, the interface is well-known and self-explaining.

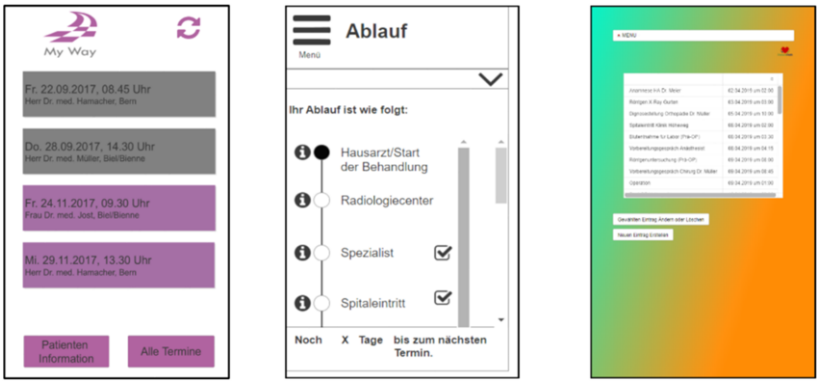

Figure 1. Three different user frontend designs developed in a competitive course.

3.3. Implementation

The prototype of the Patient Navigator App comprises four components. The first component is the Navigator App itself (fig 2 left side), intended for use by the patient on a mobile device, typically a smartphone. It presents an overview for all past and pending appointments including appointment details. Furthermore, checklists for single appointments can be added with items to be considered by the patient. Finally, the app provides an option to communicate with the healthcare providers and to ask for the rescheduling of a pending appointment. The second component is a central PathApp server which stores all appointment data of different patients. It can be connected to different IT systems in hospitals and GP practice to receive appointment updates and to transmit requests for appointment rescheduling and has been described in detail by Denecke et al. [7]. The third component is a web interface (fig 2, right side) for the physician or healthcare professional to lookup pending appointments for own patients, search for a specific patient, schedule new appointments for a particular patient, display patient rescheduling requests and reschedule appointments. In addition, the web interface supports the definition of checklists for an appointment. The web interface communicates directly with the PathApp server. The fourth component is an interface to the PathApp server which is able to process incoming HL7 V2 SIU messages for new appointments from e.g. a hospital information system.

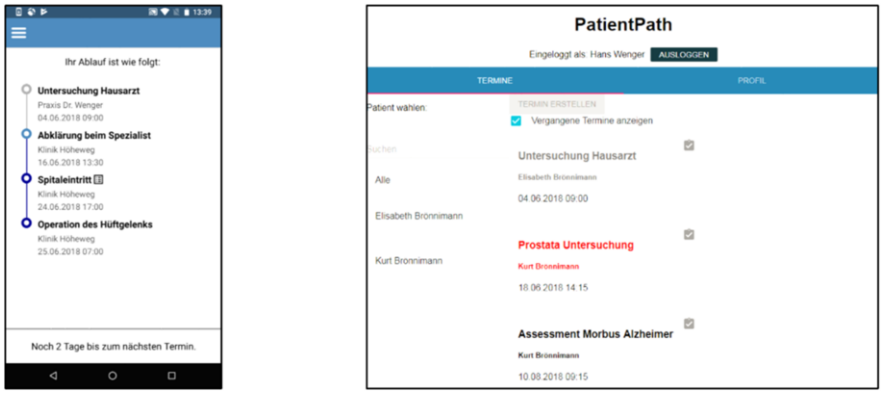

Figure 2. Lab prototype of patient navigator app. Left side shows the patient view on a mobile device. Grey past appointment, dark blue future appointments, light blue next appointment. Right side web interface for healthcare professionals. All appointments of own patients. Grey past appointment, red appointment where patient requested rescheduling, black future appointment (different patients).

It turned out to be difficult to establish a direct communication from information systems to the PathApp server. Even in the comprehensive laboratory environment with two installed GP information systems and more than three available clinical information systems from various manufacturers we could not establish direct communication. Manufacturers were contacted, but some of them completely declined the ability to export appointment data. Others presented proprietary interfaces, which, however, were not available within the systems implemented in our laboratory. One manufacturer declared to be able to communicate standard HL7 V2 SIU messages, but it turned out that this communication interface was not configured correctly.

4. Discussion

Clinical Pathways inside institutions [1-4] have their proven merits, although one could ask the question, why they are not more widely used in inpatient care [13]. There are few studies, which examine the additional value of software support for clinical pathway management [14]. Cross institutional clinical pathways are even more complex and often still under evaluation [15]. Therefore, the following summary has to be taken with caution, since a clinical evaluation of our development is still pending.

We do think, that the Patient Navigator App has the potential to improve interaction with healthcare professionals and offers a chance that more appointments can be better scheduled and attended. Appointments are more likely to be successful if all checklist items are completed by the patient. During inpatient stay, provision of pathway information for the patient can be a value added function of the respective healthcare institution. Thus, the app could contribute to patient satisfaction and patient empowerment.

Lessons learned:

- Elderly patients use modern information technology on a regular basis.
- They agree to use an app for trans-sectoral guidance through a healthcare episode.
- Patient requests for rescheduling should be supported.
- Competitive programming provided a minimalistic interface, which, according to potential users, was easy to use.
- To avoid additional workload for healthcare professionals, the app must be interfaced with the clinical systems acting as the master for appointment data.
- The resulting system architecture was more complex than expected and requires a dedicated Path App Server.
- None of five different clinical information systems could be timely interfaced.
- For interaction with the future Swiss Electronic Patient Dossier CDA formats for appointment data will be required.

Before we started our activities, we searched app stores and literature for comparable applications. We found several apps, e.g. a German app for hip TEP patients [16], but none which interfaced to clinical systems and was able to support rescheduling of appointments in a generic fashion. That, however, although technically demanding, has been highlighted as a desirable added value for a Patient Navigator App.

From other projects, we have information that a considerable number of outpatient appointments in hospital departments fail because the patient doesn't turn up. This causes loss of time for the healthcare professionals and expenditure for the institution. Although we implemented a dedicated web interface for healthcare professionals, we do not consider it a viable solution, due to the extra effort required to deal twice with appointment data. Instead, a direct information flow from clinical systems in GP practice and hospital to the Patient Navigator App is essential, maintaining the role of appointment master within the clinical IT systems. HL7 V2 offers a message based solution to transmit and alter appointment data and has been implemented as a first interface. It is typically used in inpatient environments. We could not identify a viable alternative for the many GP information systems available in Switzerland which currently do not support a common communication standard for appointment data. A master patient index is necessary to combine appointment data from different institutions for a single patient on the PathApp server.

From 2020, Swiss patients will be entitled to obtain an electronic health record (EPD) based on CDA and IHE xds.b profiles [17]. An MPI will then be available on a community level. Today, Swiss CDA level 3 appointment structures have not yet been defined and our next efforts will concentrate on this topic. It will remain an open issue if the Swiss EPD environment could then completely replace the current PathApp server in its functionality. This would offer the advantage that clinical systems shall be anyway interfaced to the EPD.

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Making the Radiology Workflow Visible in Order to Inform Optimization Strategies

Dominique BRODBECK[a,1], Markus DEGEN[a], Rahel LÜTHY[a], and Tobias HEYE[b]
[a] *School of Life Sciences, University of Applied Sciences and Arts Northwestern Switzerland*
[b] *Department of Radiology and Nuclear Medicine, University Hospital Basel*

Abstract. Medical imaging is undergoing rapid change, induced by the increasing amount of image data, and advances in fields such as artificial intelligence. In order for a radiology service provider to respond to these challenges, it needs to adapt its workflow. To inform optimization strategies, the way that processes and resources interact in the real world must be understood. We report on our experiences with an approach that consists of merging a variety of data sources into a data model that allows efficient interactive queries, and then providing highly interactive visualizations to explore the data. Two examples are discussed: animation of patient flow through the radiology workflow, and the use of energy consumption patterns to characterize operational modalities.

Keywords. radiology workflow, process optimization, exploratory visualization

1. Introduction

The radiology workflow is defined by how the various activities that are performed in a radiology department of a hospital and the corresponding actors are orchestrated in order to deliver the desired medical imaging services.

Medical imaging in hospitals is undergoing rapid change. Standard modalities are being commoditized, new modalities are entering the field, and the role of imaging in the treatment path is shifting [1]. New technologies based on artificial intelligence and start-up companies offer services that are changing the landscape [2]. In order for the radiology department to respond to these challenges and to improve productivity, it needs to adapt its workflow and practices [3].

Before investing in reorganizations and new tools however, there must be an understanding of current processes. The way that processes and resources are planned and scheduled in theory does not necessarily correspond to the real world situation. The workflows in use therefore need to be assessed and measured in order to enable decisions that are based on evidence.

Standard approaches try to derive KPIs (e.g. throughput, length of stay) that are displayed in dashboards, or they focus on optimizing specific steps in an individual's work process (e.g. voice recognition for dictation of reports). While these approaches provide valuable insight into specific aspects of the radiology workflow, they are

[1] Dominique Brodbeck, University of Applied Sciences and Arts Northwestern Switzerland, Hofackerstrasse 30, CH-4132 Muttenz, Switzerland; E-mail: dominique.brodbeck@fhnw.ch.

typically limited to summaries with low temporal resolution or few dimensions. They suffer from the keyhole effect [4], where only a small slice of the problem is visible at any one time, and users have to shift their point of view to see other limited slices.

In order to support sense-making [5] there is a need for tools that can answer more complex and open questions such as:

- What are the common event patterns of the workflow?
- Are there unusual patterns or bottlenecks, and why are they unusual?
- Is it possible to shift scans in time to orchestrate overall operations and optimize resources?
- And the ultimate: Is there anything interesting that could spark new ideas entirely?

In this paper, we report on our work-in-progress to develop tools and methods that can answer such questions. Our approach is based on making the radiology workflow visible in order to inform optimization strategies.

2. Methods

The methods that we use to build such tools are based on the insight that the various stakeholders do not precisely know at the beginning of the process, what data they need to see in what form in order to answer their question. Alas, in many cases the questions themselves are not known and need to be crystallized first. We therefore use the following two-step approach to iterate on a solution.

First, all the data sources that can potentially contribute to provide insights into the problem at hand are collected, and wrangled (assessed, cleaned, transformed, etc.) into a form that is conducive for analysis. Data Wrangling is a process that is often underestimated [6], and we find that we spend at least as much time on it than the actual analysis process.

Data sources include the obvious RIS and PACS systems, but also unlikely ones such as device logs, accounting systems, or energy meters. These heterogeneous sources are merged into a common in-memory data model that allows efficient interactive queries.

Second, we develop graphical representations that make the complex structures in the data visible and provide the big picture. Details are seamlessly embedded in this overview through various interface techniques (focus&context, zooming interfaces, distortion, etc.). We then provide exploratory access to this visualization with highly interactive interfaces.

3. Results

We use this approach to develop various tools for different aspects of the radiology workflow. In the following sections, we present two current examples:

- Understand the flow of patients through the different process stages of the radiology workflow
- Characterize the operational modalities of imaging devices by correlating energy consumption, device logs and RIS information

3.1. Animation of patient flow through process stages of the radiology workflow

The workflow of radiology is entirely computerized. Various systems and databases track patients as they flow through the different stages of order entry, examination, up to the reporting and discharge. While all the stages are well documented and understood, the overall workflow is never visible in its entirety.

We created an interactive animation that visualizes the current state of each patient in the radiology workflow for any given time in the past. Patients flow along their individual waterfall from top left to bottom right, leaving traces whose lengths correspond to their speed. The different stages are colored accordingly (Figure 1).

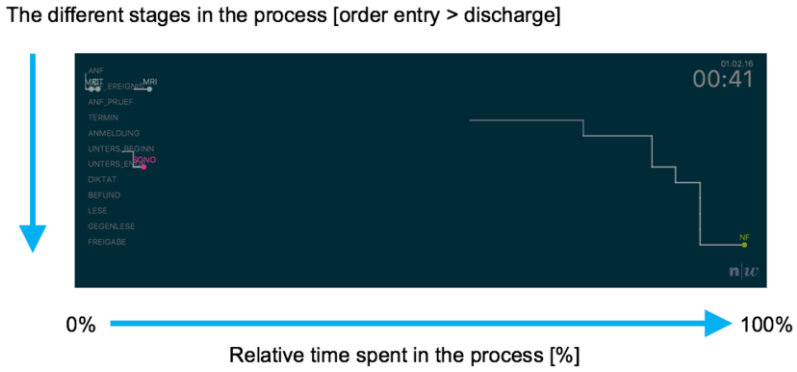

Figure 1. The visualization of the radiology workflow uses a waterfall metaphor. Each patient is represented by a colored dot: order entry (grey-yellow), examination (orange-red), reporting (blue-green). The dots flow from top left to bottom right along the x- (showing progress relative to the overall time that a patient spends in the process) and y-axes (showing the different stages in the process).

The animation can be paused at any time. An interactive time slider allows to move forward and backward in time randomly. This allows users to switch between the visually rich and cognitively dense mode when running the animation like a movie, and the possibility to examine interesting patterns in time and position in detail with fine control of the frame at a time point of interest.

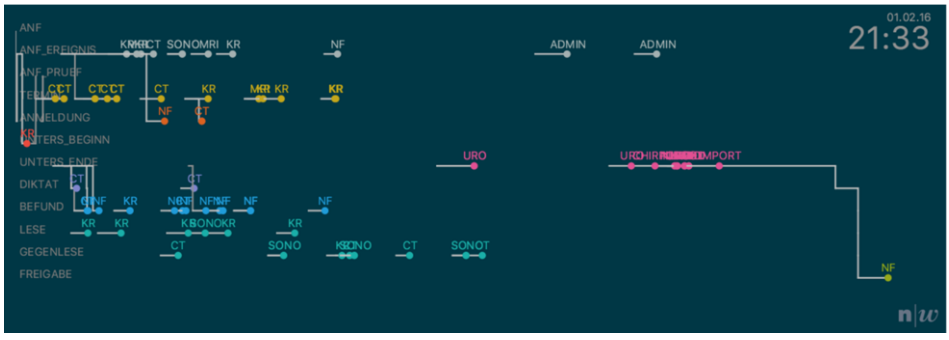

Figure 2. Animation showing patients flowing through the different stages of the radiology workflow: order entry, examination, reporting (top to bottom). The snapshot shows the state of the radiology department in the evening (21:33). At the bottom left a blue-green wave of patients is waiting for reporting the next morning. On the right side an emergency patient is moving very fast and is about to finish the process. Note that a static snapshot cannot reproduce the insights gained from watching the animation

Figure 2 is a sample snapshot from the animation during one evening, showing a wave of examinations waiting to be read and reported the next morning, while emergency cases bypass them in the fast lane. Watching the animation provides the big picture of what is going on in a radiology department at different times and creates an intuition about relationships and dependencies.

The visualization is implemented as a particle system. This makes it possible to easily experiment with different configurations of the paths that patients take along the workflow. Figure 3 shows an alternative scheme, where the workflow is shown using the metaphor of a circle, and patients travel along the perimeter counter-clockwise.

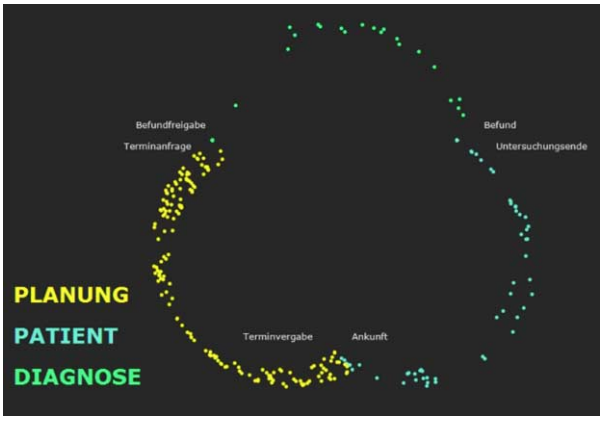

Figure 3. Animation using an alternative periodic visual metaphor where patients move counter-clockwise around a circle through the different stages of the workflow.

The first animations raised great interest with the radiologists. They add a visceral quality to the otherwise sober display of data in dashboards. Combining them with sonification could further enhance this aspect. Possible uses that we envision are as ambient visualizations in public spaces, e.g. for patients in the waiting room. The overall satisfaction of patients with their time spent in the radiology workflow, depends among other factors on how they experience the time waiting between the various stages. Externalizing the state of the workflow and a patient's position within it, has the potential to positively influence their satisfaction.

Internally, an externalization of the current state of the workflow could be used by the radiology staff to inform them about questions such as, how many patients have we already done today? How many will be coming? Will there be enough resources? Where is the bottleneck? The visual metaphor of the waterfall would have to be adapted from using retrospective historic data towards using real-time data feeds where the future is not known. We will also look further into the possibility of using such types of animations for predictive tasks.

3.2. Correlation of energy consumption, device logs and RIS information to characterize operational modalities

Energy consumption and the reduction of the carbon footprint gain increasing interest, also in a clinical context. Vendors start to advertize it as a key feature. Radiology is one of the large energy consumers in a hospital. How can you inform an energy reduction strategy?

The first step is to install energy meters for each device. But this is not enough. We need to know when an examination begins and ends, why it was done, and what happened on the other devices at the same time to assess if scans can be shifted in time and orchestrated. Next to the energy measurements (one sensor per device, 0.1-1 Hz) we used data from device logs (various formats, 103 entries per day per device, 102 event types) and RIS (20-40 examinations per device per day). All data was recorded simultaneously for one year.

There are specialized tools for each of these data streams in their respective fields (facility management, log file analysis, EHR) but they don't provide the big picture and don't allow temporal and causal correlations across data boundaries.

We therefore developed a highly interactive data exploration tool that allows visual analysis of heterogeneous temporal event sequences (Figure 4).

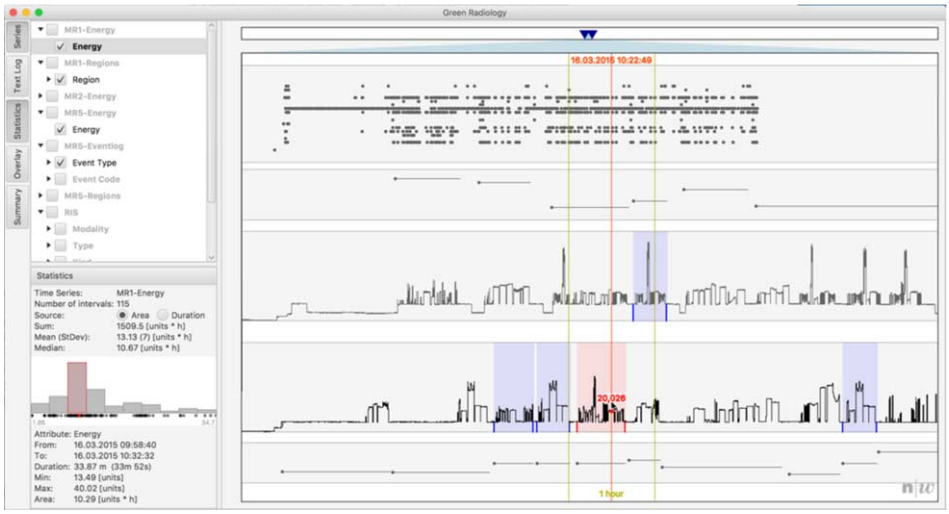

Figure 4. Data exploration tool for correlation, characterization and quantification of radiology events along time and across devices. On the right (from top to bottom): scanner log events, examination periods extracted from the RIS, and energy use of two different MRIs. As an example, head scans extracted from the RIS are marked as segments. Summary information about these segments is shown in the statistics view in the lower left panel.

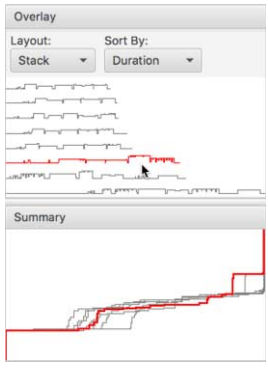

Figure 5. Additional views show a chosen segment (red in Figure 4) in the context of all other scans with the same modality, but potentially different scan protocols. The summary view at the bottom is created by plotting the sorted values of a segment in order to compare plateaus.

It features efficient navigation in time both across large time spans and between different scales by using rapid semantic zooming [7]. Signals can be correlated leading to event identification, characterization, and quantification.

Next to insights into the energy consumption issues, the data and the tool also provide opportunities for workflow analysis and process optimization. This is very interesting for the vendors of the imaging devices, as they typically do not have insights into how their devices are used in practice, outside of their controlled environments. The radiologists that are planning the scan protocols are interested to see, how what they plan matches with reality of how the scan protocols actually perform. Finally, the system was well received by the users controlling the radiology department, and various analysis initiatives are underway.

4. Conclusion

Interactive exploratory visualizations of abstract data that cover all aspects of the radiology workflow, are essential tools to explore complex relationships, detect unexpected evidence, and generate new hypotheses. They complement the operational dashboards and reporting, and have shown great potential to inform optimization strategies for various aspects of the radiology workflow.

Future work will include the evolution of the workflow animation into a real-time monitor that shows the current state of the radiology workflow, and allows to optimize operations. In another effort the insights will be used to provide feedback to patients about their position in the workflow in order to improve their experience. Results from analyzing the energy data will be used to inform energy reduction strategies, and to improve the design of scan protocols.

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Current Reasons for Not Using Clinical Pathways in Practice

Murat SARIYAR[a,1], Thomas BÜRKLE[a] , Michael LEHMANN[a] Jürgen HOLM[a]
[a] *Bern University of Applied Sciences, Biel, Switzerland*

Abstract. Clinical pathways are often promoted as the holy grail of efficient healthcare provision. However, our experiences during the Swiss research project *Hospital of the Future* demonstrated that most Swiss hospitals do not implement clinical pathways in the sense of '… a document describing the common process of a multidisciplinary treatment for a particular type of patient'. In this paper, we will discuss reasons for the lack of pathway implementations. We differentiate between three different categories of explanations: (i) organization-specific impediments, (ii) environmental hurdles, and (iii) inherent problems of clinical pathways. Without additional support and regulation by the policy maker, it seems rather unlikely that an increase of pathway implementations will take place in the near-future in Switzerland.

Keywords. Clinical pathway, process-orientation, guidelines

1. Introduction

Streamlining healthcare processes by establishing standards and transparency mechanisms for multidisciplinary treatments has beneficial consequences for the quality and cost-effectiveness of healthcare [1–3]. Clinical pathways provide a systematic way of standardizing processes using workflow documents to support the treatment process for a particular type of patient [4]. They should be distinguished from clinical guidelines, which represent state-of-art diagnosis and treatment recommendations without describing the concrete implementation of the process flow within a healthcare institution.

Process-orientation is nothing new and has been promoted by public institutions such as the Agency for Healthcare Research and Quality (AHRQ). For quality improvement, processes have to be monitored and consciously adapted and AHRQ provides standards for monitoring, documenting and supporting healthcare processes. An example is the process analysis tool for fall prevention that helps finding gaps and problems in the current workflows and helps to change these processes [5].

On the other hand, Swiss hospitals which were leading in the development of clinical pathways [6] have discontinued their development and further use (personal communication with responsible staff). Six Swiss hospitals in our research project [7] had limited use. In this context, we examined the question why clinical pathways are not implemented as often as the literature might suggest.

[1] Corresponding Murat Sariyar, Bern University of Applied Sciences, Quellgasse 21, CH2501 Biel/Bienne, Switzerland; E-mail: murat.sariyar@bfh.ch.

2. Methods

The context of our work was the Swiss research project "Hospital of the Future" [7], which aimed at realizing prototypical IT applications for a digitally enhanced future of the Swiss healthcare system. Clinical pathways were an important issue throughout the project, therefore we arranged stakeholder workshops with all project partners to obtain an inventory of existing methods and tools. We used the world-café format to discuss pathway related questions with groups of project partners and a "table host" using flip chart annotations [8]. The questions discussed in the world café are:

a) Do we already have efficient hospital processes even without clinical pathways?
b) How can we assess the costs for developing and implementing pathways?
c) What are the main hurdles for implementing clinical pathways?

In addition, we conducted a systematic PubMed search with the following keywords:

- "clinical pathways"[All Fields] AND "disadvantages"[All Fields]
- "clinical pathways"[All Fields] AND "negative"[All Fields]
- "clinical pathways"[All Fields] AND "barriers"[All Fields]

We were interested in current publications of 2018. The abstracts were screened, and relevant articles included in the study. We analyzed the information in these articles in combination with the world café results.

3. Results

The literature research delivered 0 + 6 + 8 = 14 matches. Four papers were classified as highly relevant [9,10,11,12]. Classification of obstacles for clinical pathway use resulted in three categories: (i) organization-specific impediments, (ii) environmental hurdles, and (iii) inherent problems of clinical pathways (see Figure 1).

3.1. Organization-specific impediments

In [9], a hospital funding reform based on clinical pathways in Ontario, Canada is described, and one main conclusion is that "hospitals sometimes found it easier to focus on containing and standardizing costs of care than on implementing standardized care processes that adhere to best clinical practices." Three factors relevant for clinical pathways were identified: complexity of required changes, internal capacity for organizational changes, and availability of external support to manage change. Without such supports "hospitals may enact quick fixes aimed mainly at preserving budgets, rather than to pursue evidence- and value-based changes in care management."

The workshop results corroborate these findings and add some further insights. Besides missing internal capacity and external support, it is also the lack of will to participate in the process change that constitutes an organizational impediment for the use of clinical pathways. At first, standardizing processes within a clinical pathway creates full transparency, which is frequently not desired. Knowledge and experiences represent some sort of autonomy and health care professionals may not want to disclose their implicit knowledge in order to avoid the feeling of getting more and more interchangeable and to lose their autonomy. Second, almost all hospitals are already process-oriented due to established quality management systems. Additional patient

related restrictions of the working processes have the potential to deteriorate efficiency instead of improving it.

In summary, defining, developing, and implementing clinical pathways is often regarded as too expensive or not feasible, even though the potential advantages are acknowledged. Schechtman et al. [10] investigated emergency department (ED) leader attitudes towards clinical pathways which guide admission decisions. They contacted 135 EDs and received 64 (48%) responses. Only eight sites confirmed that they had implemented clinical care pathways to reduce avoidable admissions.

3.2. Environmental hurdles

Jabbour et al. [11] conducted a qualitative study among 15 community hospitals in Ontario and describe a set of barriers and enablers in the context of clinical pathways for pediatric asthma respectively pediatric vomiting and diarrhea. As environmental factors they identified the attitude of other stakeholders towards pathways, the availability of user-friendly pathway guiding and documentation tools, and funding and public pressure, be it by regulations or through prestige issues. The group used the COM-B model (capability, opportunity, and motivation of the behavior change wheel) for the mapping and Interaction investigation of barriers and enablers. The environmental factors are mainly related to the opportunity part and have thus impact on increase or decrease of capabilities and motivations.

Within the world café, we derived another categorization: local versus trans-sectoral pathways, pressure of health insurance companies to reduce costs, and the integration of pathways within cross-institutional structures like the coming Swiss electronic health record (EHR). The main difference to the COM-B model is the focus on disabling instead of enabling factors. We tried to identify those environmental factors that pose important hurdles. One such factor is the missing network effect when no other external pathway implementations create pressure for internal adoption. As the digital change within the Swiss healthcare system is imminent, it seems important for new pathway implementations that they are part of this change; otherwise, most hospitals have duplicate work which they are not willing or able to handle.

Summarizing, the input from the Swiss healthcare environment lacks strong support for clinical pathways which decreases the motivation for implementation; especially, when other changes/structures are imposed by the policy maker. Pathways should be part of the cross-institutional infrastructure in order to support efficient trans-sectoral healthcare and to avoid additional workload. Without additional support and regulation by the policy maker an increase of pathway implementations in Switzerland seems unlikely in the near future.

3.3. Inherent problems of clinical pathways

Today we assume with some evidence that clinical pathways can and will increase efficiency, quality and cost effectiveness. But more research and better methodology is needed for the assessment of clinical pathway effects. Shanbhag et al. [12] investigated the acceptance of guideline recommendations in heart failure in a systematic review of 38 studies. Although improvements of process quality could be demonstrated in these studies, they were rarely accompanied by improvements in clinical outcome. Especially complex treatments are difficult to standardize with clinical pathways.

Our own workshop confirmed the lack of substantial outcome improvement and provided some additional insight into problems. Frequently, the following central criteria are used when deciding for and against the implementation of clinical pathways for certain types of patients [4]: (i) number of patient expected to be on the pathway; (ii) related average cost; (iii) complexity of the treatment; (iv) availability of quality indicators; (v) definite start and end of the path. Apart from the first two, these criteria are difficult to assess. Furthermore, a division between pathway patients and those without results in restricted treatment freedom in one and full treatment flexibility in the other case; a situation with potential for conflict.

Standardization of processes aims at improving the average, whereas physicians have to account for the idiosyncrasies of patients. Flexibility for multimorbid patients and variability in time and process steps are central for medicine as an art. To a certain degree, pathways can consider that, but the trade-off between flexibility and standardization should be openly discussed. Implementation of clinical pathways requires massive change management in order to obtain benefits.

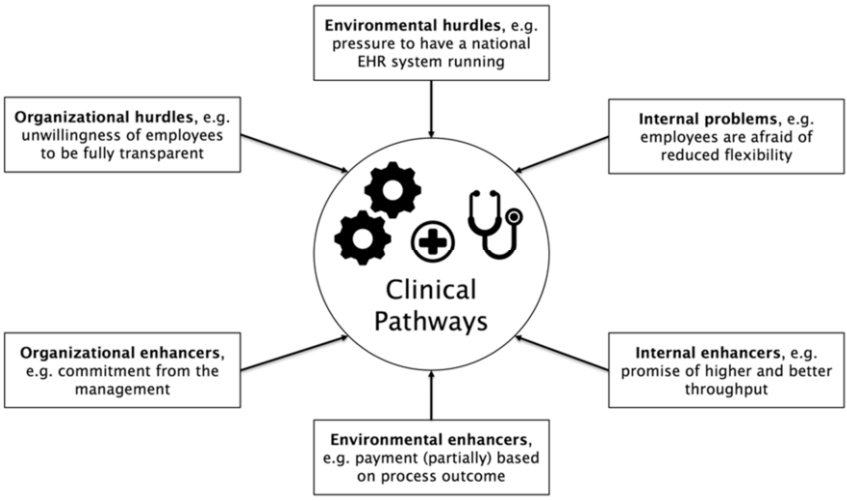

Figure 1. Hurdles and enhancers of clinical pathway implementation.

4. Discussion

Our starting point was the scarce use and sometimes even disregard of clinical pathways in Swiss hospitals. Therefore, we focused on the disadvantages of clinical pathways. We classified the hurdles for implementation into (i) organization-specific impediments, (ii) environmental hurdles, and (iii) inherent problems of clinical pathways.

We fully acknowledge the potential benefits of clinical pathways reported e.g. in [13]:

- Reduced waiting time within and between divisions,
- Reduction of the treatment costs by avoiding duplication of work, waiting times and inefficient use of resources,
- Reduced risk of treatment errors,
- Increased knowledge transfer.

Non-adoption of clinical pathways in practice is not just a matter of inherent disadvantages outweighing the benefits, but rather lacking external and organizational support. If, for example, clinical pathways cannot be easily represented in the hospital documentation systems, and if several different applications are necessary for path support, successful implementation of pathways will fail. A systematic way of process-orientation, which is supported by organizational and technological means, can exploit all of the advantages promised by pathways.

In addition to the disadvantages listed, there are also two further related negative aspects associated with pathways. On the hand, dehumanization of work is a possibility due to reduced room for creativity. A strict time schedule and a list of activities to be done in certain stages can have undesired impacts on job satisfaction. On the other hand, the relationship between health professionals and the patient can get less personal. Patients do not want to be treated as things or process elements, but as persons with dignity. Both aspects, job and patient satisfaction, go hand in hand, which means that pathways should consider room for personal exchange beyond functional requirements, leading to patient- and employee- centered clinical pathways [14].

In summary, there are indeed many reasons for not implementing clinical pathways, but none of them are insurmountable. Inherent problems of clinical pathways can be reduced by allowing more flexibility than in industrial settings, by a transparent discussion culture and by considering change management right from the start. Organization-specific impediments can be tackled, for example, by external counselling, integration of pathways into the quality management systems and by fostering interdisciplinary exchange regarding process design. Finally, environmental hurdles should be addressed by regulators with an integrative view on clinical pathways in the wider context of the digitalization in the healthcare sector.

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3. How Does eHealth Change the Care Process

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Exploring the Future Role of Self-Tracking Data in the Rheumatology Clinic

William HUE[a,1], Simon JONES[a] and Raj SENGUPTA[b]
[a] *Department of Computer Science, University of Bath, UK*
[b] *Royal National Hospital for Rheumatic Diseases, UK*

Abstract. Despite enormous growth in the use of consumer self-tracking devices, the data that many patients collect about their condition is seldom integrated into conversations that take place in the clinic. In this paper we explore the potential roles that self-tracking data could play during clinical interactions between patients with Ankylosing Spondylitis (a chronic rheumatic disease) and their clinicians. We develop a model of the data-centric activities that currently take place within the rheumatology clinic, using field observations, and to discuss how self-tracking data may contribute to each of these activities. We also interview two consultant rheumatologists regarding the opportunities and challenges that the use of self-tracking data may bring. We propose four different roles for self-tracking data in the clinic and discuss possible directions for designing to support these roles.

Keywords. Personal Informatics, self-tracking, chronic conditions, ankylosing spondylitis

1. Introduction

There is growing interest from health professionals and patients alike regarding the use of consumer self-tracking technologies (e.g., Fitbit, Apple Watch, MyFitnessPal) to inform the management of chronic health conditions (e.g., IBS [1], Parkinson's Disease [2]). While a considerable amount of research has focused on the development of sensing technologies for obtaining accurate measurements of patient activity, few studies have investigated the challenges associated with collaborative review and co-interpretation of personal tracking data by patients and clinicians in a clinical setting.

In this paper we report findings from field observations and interviews, intended to identify opportunities and challenges associated with the use of self-tracking data in clinical appointments for the treatment of Ankylosing Spondylitis, a chronic rheumatic disease. We discuss four potential roles that self-tracking data may play in supporting clinical interactions, namely; supporting agenda setting, supplementing patient-reported evidence, providing a platform for collaborative decision-making, and facilitating realistic goal setting. We conclude with suggested future directions for the design of software systems to support patient-clinician collaboration with self-tracking data.

[1] William Hue, Department of Computer Science, University of Bath, Claverton Down, BA2 7AY Bath, UK; E-mail: wz331@bath.ac.uk.

2. Related Work

Ankylosing Spondylitis (AS), is an inflammatory rheumatic disease that causes functional impairments, pain and stiffness in the spinal and pelvic regions of the human body [3]. Although AS affects only a small proportion of the population (prevalence varies between 0.1 and 2 percent), it typifies many chronic health conditions insofar as it requires a multi-faceted approach to monitoring and management. For example, AS patients are typically required to stretch and perform physiotherapy exercises regularly to optimise long term posture and mobility [4], as well as keep track of various aspects of their lifestyle, such as diet, physical activity, sleep and medication in order to maintain healthy function, whilst simultaneously monitoring pain levels and other symptoms for signs of deterioration or improvement. There are now many self-tracking technologies (e.g. wearable devices and smartphone apps) that allow AS patients to collect data relating to the various facets of their condition.

Previous studies have revealed that many patients wish to bring their own data into clinical appointments as evidence of their experiences, and to support articulation of their thoughts and questions (e.g., [2,5]). However, recent research has demonstrated that attempts by patients and clinicians to collaboratively review patient self-tracking data in a clinical environment are often unsuccessful. For example, systems for presenting data often lack explicit support for collaboration between patient and clinician [2,5], patients report insufficient engagement with data from clinicians [1,6], and clinicians often lack time to analyse data in detail [5]. Studies suggest that clinicians struggle to interpret non-standardised data formats [1], or question the accuracy and scientific basis of the data [5]. However, previous work has shown that when patients and clinicians *do* manage to collaboratively 'craft a view' of data [2], it can be mutually beneficial for guiding one another to specific interpretations of the data, supporting the management of the condition and informing the selection of treatment pathways.

Our study asks the question: "what future roles could self-tracking data play in supporting patient-provider collaboration in a clinical setting?". Our primary objectives are to understand the current activities that typically take place at patients' clinical appointments, the types of data that are currently used, and to use this understanding to propose future ways in which self-tracking data may contribute to these activities.

3. Methods

Our data collection for this study consisted of observations of scheduled clinical appointments at the Royal National Hospital for Rheumatic Diseases in Bath. Each clinical appointment was attended by an Ankylosing Spondylitis patient and their consultant rheumatologist. In addition, we conducted semi-structured interviews with the rheumatologists (Mean duration = 33 minutes), following each appointment. In total, 28 AS patients attended the observed appointments (17 Male, 11 Female, Mean age = 29.1 years, Age range = 17-72 years), with two separate consultant rheumatologists, CR1 and CR2. Following patient visits (Mean duration = 17 mins, Range = 11-27 mins), we asked clinicians to provide their opinions on the use of self-tracking data, and to describe the ways in which existing data is incorporated into clinical conversations. We recorded field notes and meeting transcripts, using these to identify distinct activities taking place in the clinic, and to identify the data associated with each activity.

4. Findings

4.1. A Model of Activities in the AS clinic

From our observations and interviews with clinicians we produced a stage-based model to represent our understanding of the healthcare process of AS. Our model reflects a care process which is divided into two recurring phases: *out-of-clinic* and *clinical check-up*. Our model (see Fig. 1) has a particular focus on the types of activities that patients and clinicians engaged in throughout the care process. We discuss the relevance of the model and its value in exploring the clinical roles of self-tracking data at the end of this section.

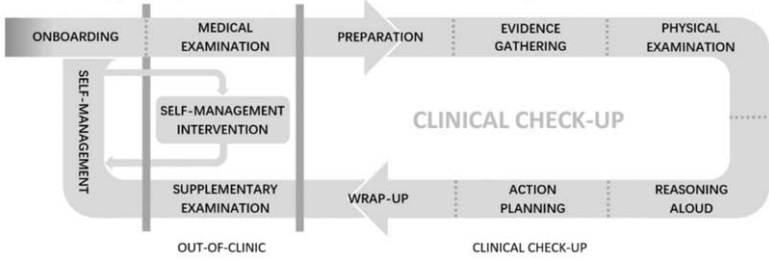

Figure 1. A stage-based model of the care process of AS.

For AS patients, a typical care process begins when they are referred from primary care to a rheumatologist, i.e., *patient onboarding*. After initial nurse- and physiotherapist-led *medical examinations* (e.g., height, weight and urinalysis assessment, and AS-specific metrology assessments such as BASMI [7] patients visit a consultant rheumatologist, thus commencing the *clinical check-up* phase. During the *clinical check-up* sessions, patients and clinicians engage in a variety of data-centric activities in a synchronous, co-located setting. These occur in the order of: *preparation*, *evidence gathering*, *physical examination*, *reasoning aloud*, *action planning* and *wrap-up*. Four distinct clinical data types were identified as being used throughout these stages: *summary care records*, *patient-reported outcomes*, *medical examination results* and *clinician-reported outcomes*. We discuss the relationships between clinical activities and their corresponding data types:

Preparation - prior to each meeting, clinicians spend 3-5 minutes reviewing clinical data relevant to the consultation, including *summary care records* (e.g., medical history, biomarkers), *medical examination results* (e.g., medical imaging, metrology indices) and *clinician-reported outcomes* (e.g., past diagnoses, consultation letters). This informs the clinician's agenda for the conversations that take place during the clinic.

Evidence Gathering - is where clinicians collect further information, necessary for making decisions about treatment and diagnosis. This evidence includes *patient-reported outcomes* (e.g. asking quick-fire questions to the patient about symptoms, drug adherence, physical activities and mental states) and *clinician-reported outcomes* (e.g., directly observing posture and gait).

Physical Examination - complements evidence gathering by allowing clinicians to collect information related to the physical condition of the patient (e.g., location and extent of pain, numbness and range of motion).

Reasoning Aloud - is a set of data-centric activities that combine sense-making and the transference of knowledge. During this process, clinicians usually make inferences based on the available data and articulate its implications to the patient using their expertise, as well as concrete clinical evidence (e.g., x-ray, MRI, BASMI).

Action Planning - is where patients and clinicians discuss and make decision about available treatment options (e.g., medications, rehabilitative courses, surgeries) alongside their implications. Sometimes, clinicians may even provide actionable insights regarding self-management (e.g., exercise, lifestyle) and set long-term targets for patients.

Wrap-Up - once an action plan has been agreed, the clinician would proceed to conclude the session by: summing up the output of the meeting, booking subsequent appointments and *supplementary examinations* (such as medical imaging and blood tests), issuing questionnaires, prescribing medications and creating a dictated letter. Once patients have left the hospital, the majority are required to engage in *self-management* of their condition. A range of *self-management intervention* programmes are made available through healthcare providers to improve patients' self-managements skills and understanding of the disease.

The stage-based model provides a structured framework that can be used to identify potential roles that self-tracking data could perform in the clinical setting and ways in which it could be integrated into current clinical practice.

4.2. Role 1: Supporting Agenda-Setting for Clinical Conversations

Our interviews highlighted the issue of conflicting agendas between patients and clinicians during check-up sessions: "*Time is really the challenge here… You have a list of things you need to get to, and patients also have a list of things they'd like to talk about*" (CR2). Conversation was primarily clinician-driven throughout all observed sessions. Both clinicians reported being acutely aware of time constraints placed on their interactions with the patient, and conscious that this reduced opportunities for patients to drive the conversation, e.g. to raise questions or concerns. Prior studies have shown that failure to elicit the patient's agenda reduces orientation of the clinical encounter toward specific aspects that matter to the patient [8]. Hence, we propose that there is an opportunity for self-tracking data (or concise summaries thereof) which convey patients' lived experiences of their condition, to be made available to clinicians at the appointment *preparation* stage. This could enable them to elicit a deeper understanding of the patient's perspective. One possible direction for future research could be to explore the development of software systems that enable patients to review and 'flag' data facets to discuss as part of the agenda. For example, knowing that a patient wishes to discuss their poor sleep, as evidenced by their tracking data, may support a more personalised and patient-centred conversation in the clinic. Significant challenges exist, however, in designing for efficient review and summarisation of data as part of an already time-constrained workflow, and ensuring that data produced by patients meets the necessary quality standards, so as to be reliable.

4.3. Role 2: Supplementing Existing Patient-Reported Evidence

Our study revealed that clinicians gave significant consideration to *patient-reported outcomes,* such as subjective reports of symptoms, physical activity and medications. Clinicians dedicated 3-5 minutes of every clinical session to the quick-fire gathering of patient-generated data for diagnostic purposes: e.g. "*When did the symptoms start to show?"* (CR1), "*No rashes? …dryness in the mouth? or eyes?"* (CR1). Clinicians relied on handwritten notes and dictated letters to record and store these outcomes, thus making data difficult to transcribe, share and analyse. CR1 expressed concerns over the ineffective use of questionnaires handed to patients at the end of clinical check-ups,

which consist of validated outcome measures such as pain diagrams, disease activity indices, and functional indices. This data is often subject to recall bias, since patients answer questions from memory, and collection frequency is dictated by attendance at clinical check-ups, often resulting in sparse datasets unsuitable for analysis. Both clinicians described the potential value of allowing patients to track their symptoms between clinic appointments and share their tracking data as supplementary evidence of their condition. Hence, designers should seek to develop clinician-facing platforms that collect and summarise this data in clinically useful formats, as a potential way of giving clinicians a richer picture of the patient's condition, and optimising the time spent *gathering evidence* during clinical consultations.

4.4. Role 3: Providing a Platform for Collaborative Decision-Making

The *reasoning aloud* stage played an essential role in establishing patient-clinician consensus and enabling collaborative decision-making. From the clinician's perspective, sharing data, information and knowledge was a way to redress the imbalance in expertise for patients, e.g. providing justification for their diagnoses and treatments. We observed several uses of clinical evidences (e.g., medical imaging, blood results) by the clinicians during knowledge transferring activities: "Do you see the whiteness there? That's inflammation forming in the bones" (CR2). However, clinicians sometimes lacked tangible data or evidence to explain their findings to patients: "I would love to sit down with the previous scores and try to incorporate it into the conversation if I could" (CR2). Some patients faced a similar issue, lacking data to provide evidence for their claims or theories: "I can only tell from my experience, but it seems to me that the effect of it (rehabilitation course) is very short-term" (P26), "(flares) seem to be getting gradually worse since I got off the pills… a lot more frequent" (P23).

We argue that self-tracking data, when presented appropriately, may be used to support knowledge sharing and collaborative decision making. CR1 expressed interest in using cohort-level self-tracking data (i.e. from many patients) as evidence to help inform patients of their projected trajectories of disease progression, for example matching patients against those with similar data profiles and using this to illustrate and inform patients about possible outcomes. Nevertheless, this hinges on the development of technologies that enable efficient data navigation, manipulation and sharing.

4.5. Role 4: Facilitating Realistic Target-Setting and Progress Monitoring

During the *action planning* stage clinicians typically tried to set targets for patients in order to improve their clinical outcomes: e.g. "*You had a BASMI (score) of 8 before the course, now it has dropped to 3. Let's try to keep it that way*" (CR1), "*Try to make stretches more regular, even 10 minutes a day makes a big difference*" (CR1). Goal setting plays an important role in helping patients to manage their condition, however patients are often demotivated when they are given unrealistic goals [9]. Inexperienced and newly diagnosed patients in particular, required a degree of guidance for realistic and achievable goals to be developed. Self-tracking data that accurately reflects a patient's' existing self-management behaviours and lifestyle could therefore support conversations around appropriate targets. At present, patients have limited opportunities to obtain measures that reflect the progression of their disease (e.g. BASMI and x-ray occur only a few times per year). CR1 reported that whilst monitoring and reflecting on these measures are beneficial, they are often costly and time-consuming to perform.

Although self-tracking data may lack the clinical rigour and reliability compared to validated outcome measures, access to data about their condition provides patients with frequent opportunities to reflect on their progress, allowing them to make adjustments to their actions and set more achievable targets based on real-time progress monitoring. However, clinicians and designers must be aware of the risk of overstating the significance of short-term targets, and losing sight of the long-term progression of the disease as indicated by traditional, validated measures.

5. Conclusion

Although both clinicians in our study were interested in the use of self-tracking data for clinical consultations, our study highlights that there is unlikely to be a one-size-fits-all solution for incorporating data into the clinical workflow. Self-tracking data may fulfil various different roles within clinical appointments and it is therefore important that tools for exploring, interacting with, and discussing data are designed to tailor and transform data to suit the demands of different activities. For example, where *preparation* necessitates grasping an overview, *reasoning aloud* often focuses on identifying patterns and correlations in data facets. The use of self-tracking data should complement, rather than complicate existing clinical activities in an already time-constrained workflow. Our work provides a model of the clinical activities which take place in the rheumatology clinic and a starting point for designing tools to leverage self-tracking data as part of these activities. We identify four roles that self-tracking data could play in a rheumatology clinic as potential directions for future research and design. Our next steps involve designing interactive systems that support data-centric interactions, using data from existing wearable platforms, for each of the identified roles and evaluating their impact, e.g., on clinical outcomes and patient satisfaction with clinical interactions.

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Managing Influenza Outbreaks Through Social Interaction on Social Media: Research Transformation Through an Engaged Scholarship Approach

Deborah BUNKER[abc1], Christian EHNIS[abc], Maryam SHAHBAZI[a]
[a] *University of Sydney Business School, NSW Australia*
[b] *Marie Bashir Institute, NSW Australia*
[c] *NHMRC Centre of Research Excellence in Emerging Infectious Diseases, NSW Australia*

Abstract. This research project seeks to develop our understanding of the spread of influenza through social interactions, individual and group activities as well as through public attitudes towards official health responses as they occur on social media platforms. We propose to conduct a series of workshops to: 1) develop a deep understanding of current social media crisis communications practices during influenza outbreaks; and 2) to assist public health agencies and health professionals to manage these outbreaks by exploring new strategies, frameworks and approaches to the potential role and use of social media platforms. The research proposal and methods outlined in this paper describe a transformational approach that bridges the divide between academics, practitioners and the general public through engaged scholarship which involves all constituent groups equally in the design, execution and co-creation of the research themes, problem focus and proposed solutions.

Keywords. Social media, social interactions, engaged scholarship, influenza outbreaks

1. Introduction

Annual influenza epidemics are estimated to result in 3 to 5 million severe cases of illness [1] that generally cause local high economic impact though the loss of worker productivity and a tremendous strain on health system often in countries with limited health resources. About 250,000 to 500,000 of these cases result in premature deaths, mainly in high-risk populations such as children, the elderly or health compromised individuals [1].

If we look at US economic data [2], in 2018 it was estimated that the average annual total economic burden of influenza was estimated to be $11.2 billion ($3.2 billion on the healthcare system and $8 billion in indirect costs). Influenza in Australia on average causes 3,500 deaths, about 18,000 hospitalizations and 300,000 general practitioner consultations each year [3]. If we assume that economic impact of flu is consistent in

[1] Corresponding author Deborah Bunker, the University of Sydney Business School NSW Australia; Email: deborah.bunker@sydney.edu.au

most developed economies, and we translate the US data to the Australian context, we see an average $848 million dollar impact p.a. on the Australian economy in influenza related costs.

In this project we propose to bring together representatives of key stakeholder groups i.e. scholars, practitioners (NSW Health, health practitioners, and impacted agencies e.g. transport, education etc.) and community leaders and members using live research methods in an *engaged scholarship* approach to collaboratively: 1) identify and understand the scope of influenza impact to the community; 2) work on effective social and behavioural strategies and solutions to combat influenza transmission; and 3) use these strategies to enable more effective and better managed health crisis communication approaches (focusing on the use of social media) to impact and help contain influenza outbreaks.

This paper firstly outlines issues with current approaches to dealing with influenza outbreaks. The gap in our knowledge and understanding of the spread of influenza through social interactions, individual and group activities as well as through public attitudes towards official health responses, is then highlighted. We then outline the relevance of social media as a platform for crisis communications in the management of influenza outbreaks. The aims and objectives of our project, our proposed research methods and their relevance to the research problem are then explained. We then describe our transformational engaged scholarship workshop approach as a problem/solution co-creation method to enhance our research contribution.

2. Dealing With Influenza Outbreaks and the Potential of Social Media

While influenza vaccination is a recommended way of containing most outbreaks [1] it is not always available, affordable, easily administered or efficacious. Reduced efficacy is more likely when there is a major shift in the genetic makeup of an emerging influenza strain. We also know that treatment with antibacterial medicines (antibiotics), which have no activity against viral infections, is frequent [4].

Such treatment may cause significant unnecessary side-effects and is costly [4]. In the longer term, high (and prolonged) exposure to antibiotics leads to increasing antibiotic resistance among bacteria, as is now occurring globally [4]. As a result, highly resistant infections that may not respond to antibiotics are increasingly reported. At the same time simple protective measures to prevent spread of influenza, such hand washing and reducing exposure of uninfected individuals, are not universally followed.

Influenza has similar symptoms as many other infectious diseases such as the common cold. Because of these similarities, the general public, as well as health professionals, often misdiagnose cases of influenza. So far the only reliable way of diagnosing influenza is based on laboratory testing. Therefore, most modelling of contagious disease transmission, including influenza, relies on information provided by public health units and laboratories.

This modelling is mostly limited to tracking cases of the disease (itself) and reasonable assumptions about how it will be managed by the public health system and private practitioners i.e. influenza vaccinations and antiviral medicines, rather than how a pandemic could be managed as a set of: *social interactions* i.e. the way that individuals, groups and communities interact and organize; *essential individual and group activities* i.e. economic and social activities such as work and looking after families; and *pprevailing attitudes and expectations* both from the general public and health agencies

and professionals towards treatment regimens such as the administration of vaccinations, antibiotics and antibacterial medicines.

Social media is emerging as an area of importance and influence on our social interactions, individual and group activities and prevailing attitudes [5] [6] [7]. The adoption and use of mobile devices, such as smart phones is lowering the cost of using social media platforms even further, but also means that valuable information is being shared in an ad-hoc manner and that not everyone is aware of this information or is "in the loop" [8] [9] [10].

Due to the range, reach and pervasiveness of these communications platforms on our everyday life, our understanding of how they impact crisis communications during an epidemic event like influenza is important [11]. The research of social media utilisation around infectious diseases can be roughly divided into communication around the disease and surveillance of the disease [12]. The results of influenza outbreak surveillance through social media analytics are, however, of limited use as symptoms are often misdiagnosed.

Research on social media communication to manage influenza outbreaks is still in early stages [12]. Current social media research is also mainly focused on specifying and developing social media analytics, that can be applied to the search, filtering and analysis of social media messages and message types [13] [14] [15] [16] [17]. While some aspects of social media are regulated and policed, authorities have very little control over the messages exchanged on social media platforms and their volumes that make social media monitoring and analysis difficult [18] [19]. Message volumes and communications on these platforms often get out of hand in extreme events like pandemics, limiting the effectiveness of using social media analytics approaches to address problems such as the monitoring and management of contagious diseases.

3. Project Aims and Objectives

In order to better understand the spread of influenza through social interactions, individual and group activities as well as through public attitudes towards official health responses our project aims to develop: 1) an understanding of public social interactions, activities, attitudes and behaviours during influenza outbreaks, including an analysis of social media communications during an influenza "event"; 2) an understanding of the current role of public health agencies and health professionals in managing these outbreaks; new strategies, frameworks and approaches to the potential role and use of social media platforms to assist in the management of influenza outbreaks and their impact, in both the short and long term.

A state audit of NSW Health capability to respond to a human to human pandemic [25] exposed weaknesses in the planned response, in particularly the recording and tracking of cases in real time, but also in areas of capacity, logistics, technology and communications. *"The public health system is well organised to respond to an emergency incident. It is increasingly better organised to respond to an infectious disease epidemic or pandemic, but there is more to be done" [25] - page 4.*

We believe it is now time to tackle this problem from a multi-disciplinary/academic-practitioner perspective that will analyse the problem from multiple viewpoints and present a solution that is created by and includes all stakeholders, thus ensuring an effective outcome where problem understanding and ownership is assured throughout the project.

4. Proposed Research Approach and Outcomes

A multi-disciplinary project co-ordination team will take an *engaged scholarship*[2] approach [20] [21] [22] to co-creation of project objectives, research problems and solutions from a health systems perspective, in order to ensure that:

- The right mix of suitably qualified project team members/research participants can be quickly identified, acknowledging that many health professionals are qualified researchers and practitioners. We have access to extensive researcher and practitioner networks, with the ability of outreach to the general public;
- A deep understanding of the key role public health agencies and health professionals play in managing and influencing such a scenario is developed i.e. knowledge of the current techniques, strategies and approaches that are deployed by them during these outbreaks; and
- A deep understanding of the current, emerging role of social media platforms in communications is developed i.e. influential "actors", sources of trusted information, impact on convergence behaviour (on the event).

Within this project we will take a basic approach to a collaborative form of engaged scholarship i.e. workshops, so that all research team/project members can gain insight together and inform each other to develop a deep understanding of problem and co-create relevant and cohesive solutions. "*We also believe that diffracting academic and professional expertise contributes to each other's development and can contribute to generating innovative ideas"* [22] - page 114.

We are firstly designing a series of workshops involving co-production and framing of a research agenda, problem focus and solution set with our academic/practitioner/general public workshop participants. These workshops will focus on surfacing the key issues in influenza scenarios; health sector roles and responsibilities and identification of interactions, activities, attitudes and behaviours that have the potential to be influenced in relation to social media communications. Effective communications strategies will then be co-created by workshop participants.

The workshop design follows a similar blueprint to a previously successful project that includes: 1) improgaphy - for structured presentations and unstructured discussions; 2) collaboration - bringing together academics/practitioners/general public to co-create a research agenda, problem statement/s and proposed solutions from all perspectives; and 3) creativity - improgaphy facilitates all workshop participants to put their ideas and suggestions forward without "fear of failure" [23] [22].

Once a workshop begins, researchers/practitioners/general public engage with each other without taking control of the course or direction of the discussion, emphasising and respecting the equality of experience of all participants from their own perspective. "*No field is superior to any other"* [22] – page 114.

Project outcomes will include: 1) the *co-production of a comprehensive model* of public social interactions, activities, attitudes and behaviours during an influenza outbreak, documenting a typical influenza epidemic "event scenario" with the general public and health professionals (identified through the research team and their networks)

[2] Scholarly/practitioner/general public knowledge of the problem is very different, but related, and research relevance and rigor are not separated but achieved together and through a symbiotic process; "Relevance is a process to be embedded in the research and not an outcome of research"; and the interactional relationship and associated practices between scholars, practitioners, and the general public are an "intermingled" contribution to the overall development of the problem and solution set.

using a variety of research methods i.e. soft systems methodology (SSM); rich picture techniques; hermeneutic analysis; and actor network mapping etc.; and 2) *development of strategies and approaches to increase the potential of social media platforms* to support public health agencies in managing and influencing an influenza scenario to limit contagion (as well as change attitudes towards social interactions, attitudes and behaviours that cause both short-term disabilities and deaths and long term health issues like anti-microbial resistance).

4.1. Justification of the Research Approach

Our engaged scholarship approach differs in important aspects from existing workshop methods where an academic research team sets the research agenda and controls the workshop structure and discussions [24]. Our approach aims for the co-creation and reframing of problems and solutions by all workshop participants. Hence, it is not limited to simply analysing existing knowledge and modes of thought. Importantly, our engaged scholarship approach allows for new thinking about and deep understanding of the research area that participants i.e. academics/practitioners/general public develop through their participation in the workshop.

Our approach also presents and re-presents the research agenda, problems and solutions in real-time; as participants work through cycles of discovery, framing and co-creation throughout a workshop. We would hope that this would also spur some of our workshop participants into action in their own workplaces to initiate solutions due to the immediate impact of this approach as a catalyst on their current method of problem identification and solution building.

5. Conclusion: Potential Research Contribution

This research project seeks to address an issue of national and international importance and value while being informative to the development of government policy. By using an engaged scholarship approach we also seek to raise general public knowledge and awareness about influenza outbreaks, the spread of the disease and the consequences of poor scenario management and ineffective subsequent treatments, throughout the life of the project.

An initial project outcome will be to develop a deeper understanding of public social interactions (influenza scenarios), public health techniques, strategies and approaches (response) and the current use of social media platforms to influence social interaction, activities, attitudes and behaviour. We will then use this understanding to design strategies and approaches to the future use of social media [18] to effectively support influenza containment and minimize economic and short and long-term health impacts.

This will be achieved through our innovative “health systems” project approach to the development of a translational solution to this problem. It is also hoped that this approach will also serve as a model for improved containment of outbreaks caused by other infectious agents transmitted between humans (and animals).

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Streamlining Hospital IT Improving the Admission Process

Jürgen HOLM[a,1], Fabian KAMMERMANN[a], Philipp NOSER[a], Murat SARIYAR[a], Thomas BÜRKLE[a]
[a] *Bern University of Applied Sciences, Biel, Switzerland*

Abstract. We analyzed the admission workflow in three Swiss hospitals of different size for normal and emergency admissions. Our goal was to detect shortcomings mainly in the administrative admission process due to media breaks. We obtained 9 different workflows (three per hospital) and a total of 22 shortcomings in the admission process which were present or likely in two or more of the hospitals. A considerable number could be traced back to missing information requiring time consuming extra work. We drafted five potential IT-based workflow changes and made, together with the hospital partners, a cost-benefit analysis which solution would be most interesting. As a result, a concept for an open multi center hospital admission portal was drafted, which, in theory, should influence 8 of the 22 problems found. Specifically, the prototype of the portal was designed for a direct triangular interaction between the referring doctor, the patient and the hospital staff.

Keywords. Hospital admission, workflow, IT portal

1. Introduction

In a Swiss research project, we cooperated with several Swiss hospitals to improve the patient workflow with current IT-technologies [1]. In discussion with hospital staff, problems in the transition between outpatient care and inpatient stay came up on several occasions, e.g. media breaks, paper based communication and duplicate data entries. We took the opportunity to examine the admission workflow for the use case of a patient undergoing hip surgery. Studying the literature [1-6] we found some evidence that this is not a specific problem of the hospitals we were in contact. Therefore, we decided to perform an in depth analysis of the admission process assuming the following hypotheses:

- During the admission process media breaks are likely
- Admission workflows will be different between hospitals but commonalities should be present
- We expect to find at least some shortcomings which could be improved with the help of IT and cross-sectoral eHealth connectivity

[1] Corresponding Author Jürgen.Holm, Bern University of Applied Sciences, Quellgasse 21, CH2501 Biel/Bienne, Switzerland; E-mail: juergen.holm@bfh.ch.

2. Methods

A literature search was conducted in Google Scholar, PubMed and BMJ with search words such as admission process, hospital admission, patient entry workflow or hospital admission standard workflow.

Three Swiss hospitals with 200, 250 and more than 1000 beds and between 10'000 and 45'000 inpatients/year participated in this project. The average inpatient stay varied between 5.2 and 5.8 days. A stepwise workflow analysis was performed using the method of Gerken [7] which has been successfully employed in former medical informatics projects [8]. It comprises analysis of organizational structures, forms and paperwork, data items, actions, workflows, communication structures and shortcomings. The latter was the main focus of this work.

Analysis started with an open interview and collection of typical admission paper work in each hospital. A previously drawn default admission workflow served as an interview guideline. Focus were the administrative and to some degree the clinical admission activities to the stage where the patient arrived on the ward. Workflow diagrams were implemented using event driven process chains within Aris [9]. Results were fed back by repeated email contact to the stakeholders. Based on the analysis different IT-based workflow changes were drafted, comparatively evaluated and again discussed with the stakeholders via email or in secondary interview sessions. Explicit confirmation of correctness of the workflows and the detected shortcomings was obtained.

A cost-benefit analysis for five solution proposals was made and defined the demands for an open access hospital admission portal. It's prototype was implemented using a content management system (word press) with the Form Maker Pro plugin. The portal was installed in an XAMPP Apache PHP development environment on windows server 2016 with MySQL database. Adaptations of the CMS database were performed using PHPMyAdmin.

3. Results

3.1. Workflow analysis and weaknesses

For each hospital, 3 comprehensive workflows comprising between 16 to 29 processes plus associated forms, IT-applications etc. were described and consented by the interview partners. The following basics were found in all three examined hospitals: Four different admission types must be distinguished: regular planned admission with referral by GP, self-referral by patient, emergency walk-in admission and emergency admission via rescue services. Regular admission in all 3 hospitals is organized via outpatient clinics and results in most cases in planned hospitalization at a later date. Emergency admission includes typically an emergency triage (e.g. Manchester) and distinguishes at some stage (especially for walk-in cases) between outpatient care and required hospitalization for treatment. In referral cases, information is required from the GP, but, in addition, information and consent from the patient is also needed. Signed patient consent is required at some stage for all hospitalizations. For planned admissions, the hospital sends a stack of paper to the patient which includes information brochures, consent forms etc. All hospitals use IT-systems for patient registration and attempt to re-identify patients which had a former patient record in that hospital.

Some remarkable differences could be identified. In the forms analysis step we could identify many different admission forms for different outpatient clinics, sometimes even specific admission forms for a single physician working in that clinic. Detailed workflows differed considerably between the three hospitals and sometimes even depending on the department or outpatient clinic. One hospital uses team based outpatient clinics on trial basis for some surgical cases. In a team based outpatient clinic, the patient meets the responsible surgeon and the anesthetist simultaneously. In the other cases the patient goes though separate outpatient clinics, often with time gaps in-between. One hospital offers an online portal for self-registration of the patient which saves the visit at the administrative patient registration.

We detected less media breaks than expected. These breaks centered around the patient referral by GP, the documents to be supplied by the patient and the change between outpatient care and hospitalization.

The combined results of the weakness analysis are summarized in table 1.

Table 1. Results of weakness analysis for the administrative admission workflow in three Swiss hospitals

No	Weakness	A	B	C
1	Patient data reconciliation very time consuming	Yes	Yes	Yes
2	Patient consent is paper based	Yes	Yes	Yes
3	Several PIDs in different hospital IT systems	No	Unclear	Yes
4	Appointment dates for multiple consultants not ranked together	No	Yes	Yes
5	In case of name changes and anonymization, relationship between digital docs can be lost	No	Unclear	Yes
6	During consultation patient receives set of disjointed paper docs	Yes	Yes	Yes
7	There is no safeguard that patient consent has been given before intervention	Yes	Yes	Yes
8	Appointment coordination for different participants of consultation is time consuming	Yes	Yes	Yes
9	Outpatient clinics make appointments without consultation of the patient, requiring rescheduling	No	No	Yes
10	Most patients do not know the mechanism for online registration	N/A	N/A	Yes
11	Patient receives invitation for appointment prior to verification of information	N/A	No	N/A
12	If GP performs online registration, but data needs to be manually transferred to hospital information system	N/A	N/A	Yes
13	Most patient communication is via Outpatient clinic w/o information of central admissions	Yes	Yes	Yes
14	In multiple visits patient receives redundant information brochures	Yes	Yes	Yes
15	Despite structured registration forms 70-90% of admissions is done by manual fax or telephone	Yes	Yes	Yes
16	Patient is used as information carrier	Yes	Yes	Yes
17	Patient must phone up hospital to find out appointment date	Yes	Yes	Yes
18	Due to paper archive, comparing information is difficult	Yes	Yes	Yes
19	Communication between hospital and patient is by phone or mail	Yes	Yes	Yes
20	Allocation of data access on change of admission status is manually	Yes	Unclear	Yes
21	Inconsistent registration forms even within on clinic	Yes	Unclear	Yes
22	Informal appointment making by GPs requires additional enquiries	Yes	Yes	Yes

3.2. Concepts for improvement and prototypical online portal

Based on the analysis results five IT-based proposals to improve the admission process have been defined, analyzed and discussed with the stakeholders (table 2):

Table 2. Five IT based proposals to deal with the problems in the admission workflow.

No	Solution proposal	Could influence
1	An online portal which synchronizes the calendar of the different hospital physicians (e.g. surgeon, anesthetist) for patient referral with access for the patient.	4,7,8,9,17
2	An online portal with synchronized referral forms for the referring GP and with access for the patient to upload data	12,15,21,22
3	Centralized dispatch and collection of digital forms through central admission	6,14
4	Digital provision of all outpatient clinic docs for the patient	6,14
5	Direct digital document exchange between referring GP and hospital	N/A

In the cost-benefit analysis a combination of proposal 1 and 2 was selected to serve as the basis for a prototypical realization. An online portal which on one hand synchronizes the calendar between different caregivers, and, on the other hand, synchronizes the different referral forms has the potential to influence the problems No 4, 8, 9, 12, 15, 17, 21, 22 from table 1. This provided the requirements catalogue for a prototypical open access hospital admission portal. The portal should support the common parts of the admission workflow found in all three hospitals and needs functionalities for the calendar synchronization (proposal 1) and for the document synchronization and digitalization. Open access, in this case, stands for a portal where several hospitals cooperate together and where not only the referring GP, but also the patient gets access to receive and upload documents. Thus a triangular information exchange between the referring GP, the patient and the hospital staff can be realized.

The portal prototype, realized with a CMS and plugins plus some additional programming (figure 1) supports multiple forms for multiple hospitals which can be defined in a near paper like format. User access can be limited for the different actors. Email notifications can be generated e.g. when the GP has completed the referral. Also, appointment acknowledgements can be sent via email. Calendar synchronization of the prototype relies on open access calendar tools. This is a known restriction which would prevent its use in clinical routine.

An example for the desired triangular information exchange is the way how the prototype supports data exchange. The referring GP, together with the patient, searches an appropriate date for the coordinated appointments at the outpatient clinic of a selected hospital. The calendars of the clinics would be synchronized with the respective hospital information system. GP and patient can freely choose between those hospitals who participate in the portal. The GP fills his parts of the referral form for this clinic. Next, the patient receives a link to the portal via email with the invitation to fill his parts of the admission documents and to download the specific information brochures for his case. All data which was previously documented by the GP is already present and must not be repeatedly entered. The summarized data of patient and GP is available for the hospital physician and administrative staff.

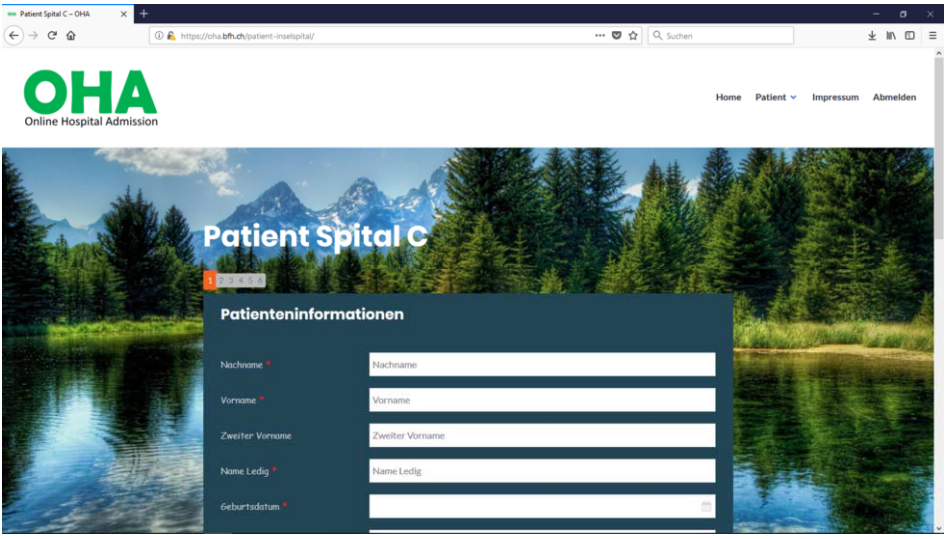

Figure 1. prototypical online hospital admission portal, opened with a patient form. Entries which the referring GP made previously are present (in this case dummy data).

4. Discussion

Hospital portals are established technology. Initially used to offer the patient access to his medical data and prescriptions [11, 12], they are increasingly used for appointment making as well [13, 14]. These portals, however, are often specific for a single hospital or a hospital chain [11, 12, 13]. Thus, they usually do not offer the option for the referring GP to select, together with his patient, among several hospitals. Only recently, first publications report about the effects of linked portal platforms [14]. Typically, evaluation studies report the use of the portal, i.e. how often a function was accessed [12,13], sometimes in relation to the use of inpatient services, occasionally in relation to outcome parameters such as readmission [14].

Our approach focused on the transition process between outpatient and inpatient care. Thus, we started, similar to [15], with a workflow perspective. In this process we identified shortcomings and weaknesses in the admission process of three Swiss hospitals. The portal prototype is a compromise with the goal that all three hospitals could profit. Team or group specific requirements within an institution can be supported in its architecture. The design acknowledges that an existing admission portal of one of the named hospitals is sparingly used, therefore we tried to optimize data reuse and to avoid unnecessary data entries which may deter patient or care provider from portal use.

Desirable functionality such as synchronization of the calendar data with the GP and the hospital information system are yet unsolved in the prototype. A master patient index is required. Documents which must be signed by the patient (e.g. consent forms) need printout or an additional digital signature process with the respective authentication mechanisms. Security issues and complicated access rights (administrative versus clinical staff) must be solved when data is pooled for several hospitals and their patients.

Nevertheless, we see a tendency to move from hospital specific portals to shared structures [14]. Switzerland is introducing an electronic health record (EPD) based on CDA and IHE xds.b profiles [10]. The EPD per se does not solve the workflow problems

described here. It is not suitable for calendar synchronization or for appointment scheduling of a hospital or a clinic. It does, however, contribute to an improved IT infrastructure for cress-sectorial communication which could help to push additional developments such as the open hospital admission portal described here, and it will provide a master patient index. But, initially, a portal solution must be functional also for patients without an EPD. The Swiss EPD is optional for the patient, whereas an institution such as a hospital should provide an admission service which is functional for all patients.

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Components for Material Master Data Management in Swiss Hospitals

Michael LEHMANN[a,1], Marwin PHILIPS[a], Claudia TELESCA[a], Murat SARIYAR[a], Jürgen HOLM[a], Erwin ZETZ[b], Thomas BÜRKLE[a]
[a] *Bern University of Applied Sciences, Biel, Switzerland*
[b] *GS1 Bern, Switzerland*

Abstract. The material master data catalogue in large hospitals may well exceed 50'000 articles required at one or another location for patient diagnosis and treatment. Most hospitals use a commercial material management IT system to deal with orders, eProcurement, incoming goods, warehouse management, internal commissioning and distribution. An analysis in three Swiss hospitals (including a hospital chain) demonstrated however, that despite existing standards maintenance of the material master data catalogue is often done manually based on different incoming formats such as csv, mail etc. We present components, which may enable seamless master data update using standardized formats and discuss in detail current barriers within hospital supply to give finally recommendations how to overcome them.

Keywords. eProcurement, Master Data Management, Supply Chain

1. Introduction

Material master data describe the reference description essential materials within an organization. In clinical settings, these are description, for example, of swaps, bandage scissors or injection syringes. Quality of processes and outcomes depend on well-documented, harmonized and valid master data, which also guarantees that orders from the departments are related to the desired materials. Usually, ten thousand of materials are needed, which makes their management challenging, even though most of the items should be stable in the medium-term. The actual amount of data to be managed depends on the granularity of the product to be described. The less detailed a description is, the less is to be managed, the more flexible can the ordering be, but the less precision is possible.

One central problem for material master data management is the gathering and updating of information, especially when there many different deliverers. Data exchange between a hospital and its deliverers is important for having updated information about available material. There is, however, often no standard update procedure within hospitals and no overview about available infrastructures and technologies. This is not only related to the connection between the end consumer and the material provider, but also to the whole chain of deliverers from raw material to the end product.

Here, we investigate whether there are automatable solutions for standardized material data management available that could be adopted by hospitals. For example, the

[1] Michael Lehmann, Bern University of Applied Sciences, Quellgasse 21, CH2501 Biel/Bienne, Switzerland; E-mail: michael.lehmann@bfh.ch.

catalogue item notification (CIN) standard proposes to unify the data update mechanism for materials based on other standards such as the global trade item number (GTIN) for uniquely identifying products or the global location number (GLN) for uniquely identifying deliverers. We are assuming a running hospital that wants to increase efficiency and data quality that is associated with providing up-to-date material master data. Out of our scope is the question of how material master data can be established.

2. Methods

The context of our work was the Swiss research project "Hospital of the Future", which aimed at realizing selected prototypes for a digitally enhanced future of the Swiss healthcare system. Within this project, material from two previous student projects could be used. A bachelor thesis from 2015 examined the complete hospital supply chain from the manufacturer to the patient for medications together with B. Braun Medical taking intravenous solutions as an example and devised a method for closed loop medication with barcode scanning at the bedside [1]. A student project from 2017 analyzed and described the process chain for eProcurement in hospitals and examined the use of 2D-Barcode, RFID and scales for material weighing operations at the hospitals incoming goods inspection [2].

Semi-structured interviews were conducted with the responsible persons for material management of a Swiss university hospital *A*, a Swiss hospital chain with 16 hospitals *B* and a Swiss regional hospital *C*. Further, interviews were conducted with a large supplier (Johnson&Johnson), a logistics company (Kühne und Nagel), two electronic data interchange provider (EDI provider) specialized on hospitals and a responsible person at GS1 Switzerland (coauthor E. Zetz). Results were collected for a summarizing report within a students' project.

3. Results

3.1. Current situation in the three hospitals

Typically, material master data comprises at least the following fields which are, for example, available in the SAP MM (materials management) system: (i) item designation, (ii) unique item ID, (iii) one or several article classifications, (iv) packaging sizes, (v) specific storage requirements, e.g. temperature or dangerous goods advice, (vi) storage location(s), (vii) minimum quantity, (viii) minimum order quantity, (ix) price, (x) manufacturer and distributor. The analysis showed an interestingly different situation for the three Swiss hospitals, even though all three used the SAP MM and its material master data catalogue for orders, incoming goods, warehouse management and internal commissioning.

Hospital *A* maintains a (shadow) material master data catalogue with a tool of Consense GmbH. This catalogue allows digital updates, mass data import and digital interfacing. After cleansing, its content can be transferred to the SAP MM system which has a material master data catalogue with approximately 50'000 articles. The SAP MM is connected to a digital hospital ordering system.

Hospital chain *B* has recently established a centralized data warehouse (ZENLOP) for currently 14 of the 18 hospitals, which stores 4'700 of the total 60'000 articles listed

in the MM system of the hospital chain [3]. eProcurement is established for orders with many suppliers, but update of the material master data catalogue is a manual process using different formats and catalogues from the various suppliers. Problems arise, e.g., if a manufacturer changes the package sizes, which in the worst case, is only detected upon delivery at the data warehouse and causes problems.

Hospital *C* with 14'000 articles is part of a purchasing organization together with two other hospitals. All three use the same EDI provider, which provides an own material classification with 17 levels and 180'000 classes of materials. The provider supports the hospitals with an own (mapped) master material catalogue, which is imported into the hospitals SAP MM. For the hospital procurement staff, a digital tool is available which supports the search for substitute products among all suppliers cooperating with the EDI provider based on the named large material classification. Figure 1 depicts the current situation for hospitals A and C.

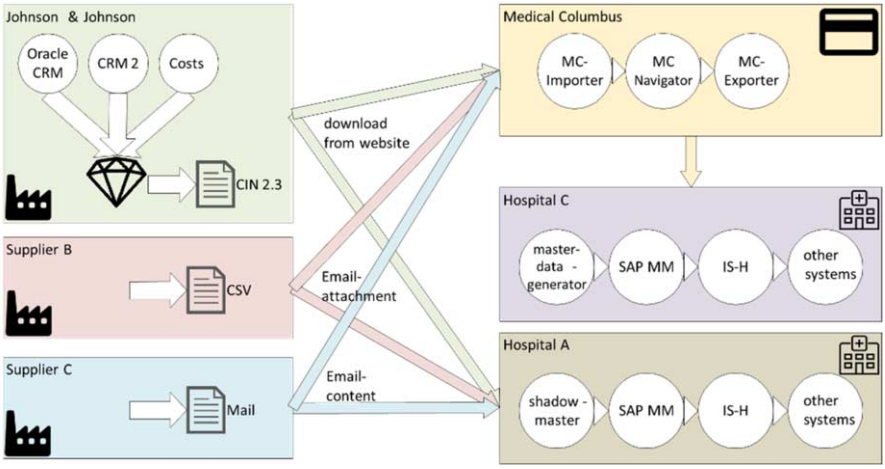

Figure 1. Current situation. Left side three exemplary supplier, right side one EDI provider connected to hospital C and standalone hospital A. Material master data updates arrive via several communication channels (email, download) in different formats at the hospitals.

3.2. Available standards and classifications

For the supplier part the following facts could be derived: Depending on size of the manufacturer and level of digitization the quality of material master data is varying. The GS1 standard Global Trade Item Number GTIN (formerly EAN) [4] is established in the Swiss healthcare system and has, for example, in 2012 replaced the former Pharmacode for drugs. It doesn't solve, however, the master data problem. There are cases where one manufacturer used more than 150 GTIN numbers for the same article depending on time of manufacturing, package size and various other factors. This can cause problems within hospital IT systems who often do not support more than 10 GTIN numbers for one article. For material master data exchange GS1 proposes the Catalogue Item Notification CIN messages [5,6]. There are two versions. CIN version 2.3 is based upon csv messages, whereas CIN version 3.1 [6] is based on XML. CIN uses GTIN for article and package identification and the Global Location Number GLN [7] for the identification of the manufacturer and provider. Country specific extensions can be defined and GS1 Switzerland has thus defined a local extension px13 Healthcare Information Module for

the Swiss healthcare system. Johnson&Johnson for example can currently deliver material master data with CIN 2.3 for about 80'000 articles available in Switzerland on a weekly basis. This, however, requires considerable effort using three different IT systems within J&J for data maintenance. Many small companies are still unable to deliver such data.

In addition, GS1 provides a standard network support for the automated exchange of material master data with a publish – subscribe mechanism. The Global Data Synchronization Network GDSN [8] defines a source data pool where suppliers and sellers can upload new product data. The recipient, in this case the hospital, subscribes to the GS1 global registry and requests article information based on the GTIN. Data is transferred to the recipient data pool and published to the customer. Although the 34 global GS1 data pools contained in 2017 information about 23'000'000 articles from 41'000 sources, the system is not yet spread in the Swiss healthcare system. In the same year, the Swiss company Contentis had only 2 participants and 6 articles in their pool [9].

Classification of articles into groups and classes of materials is essential if a hospital procurement team wants to search for an alternative article with similar properties from another provider. For drugs, the WHO Anatomical Therapeutic Chemical Classification system classifies the active substances in a five level hierarchy [10]. Unfortunately, no such fully open, agreed and standardized classification is available for all materials. eCl@ss is a cross sectoral product classification with 41'000 product classes in four levels in its current version 10.0 [11]. It supports the detailed classification of medicinal products, e.g. 34 medicinal product, 34-22 iv injection, infusion and transfusion systems, 34-22-01 syringe (Medicine) down to 34-22-01-01 iv injection syringe single use. For each product class specific attributes can be defined with a choice from 17'000 potential product attributes. Although the classification itself is openly visible, it may be used only under license. We noted that eCl@ss is used in German hospitals, but it is currently rarely in use in Swiss hopitals. In our observation, hospital group B was in the process of introducing eCl@ss, although without attributes. eCl@ss can be transmitted using CIN 3.1 as AdditionalClassification. Some EDI provider such as Medical Columbus have included eCl@ss in their material master data catalogue and support navigation to alternative articles.

The GS1 alternative is the Global Product Classification GPC [12]. It has a four level hierarchy of segment, family, class and brick. For the brick, attributes can be defined for detailed specification.

Despite such options, proprietary internal classifications are common. Hospital A, for example, maintains an own internal three level classification with several hundred classes. Service providers such as Medical Columbus maintain extremely detailed proprietary classifications, in their case 17 levels with 180'000 classes.

3.3. Potential improvements

After switching to the EDI provider, the head of logistics and materials management of hospital C reported that he is satisfied with the quality of the master data catalogue from his EDI provider. In this case, the service provider has invested considerable efforts to provide a clean and well maintained catalogue to all hospitals in his customers' register. This service, however, is restricted to those suppliers with whom the service provider has payment agreements. Some articles, e.g. prostheses for implantation are not covered.

To improve the situation for Swiss hospitals we identified a problem list (table 1):

Table 1. Current weaknesses of material master data management and potential solutions

Hospital Problem	Potential Solution
Insufficient master data quality	Manufacturers and suppliers should improve source master data quality
Missing automated master data updates	Use of GDSN in combination with CIN 3.1
Unstructured communication of master data	Use of GDSN in combination with CIN 3.1
Restrictions in current MM IT systems (e.g. field length)	Improve MM IT systems for better support of healthcare requirements
Duplicate catalogue entries	Improved update control
Different use of catalogue fields	Improved education of catalogue maintainers
Complex order process	Connect to EDI provider
Difficult search for replacement articles	Use standard catalogue such as eCl@ss or connect to EDI provider.

Provided that more suppliers use the current CIN 3.1 standard and GDSN network an improved communication using the GS1 Global Registry, Source Data Pool and Recipient Data Pool of GDSN could be realized (fig 2). For classification purposes, the proprietary eCl@ss catalogue is currently better suited and further disseminated in German speaking healthcare environment. GS1 GPC has the potential to attract more customers on the long run, but would need extensions for optimal support in the healthcare area.

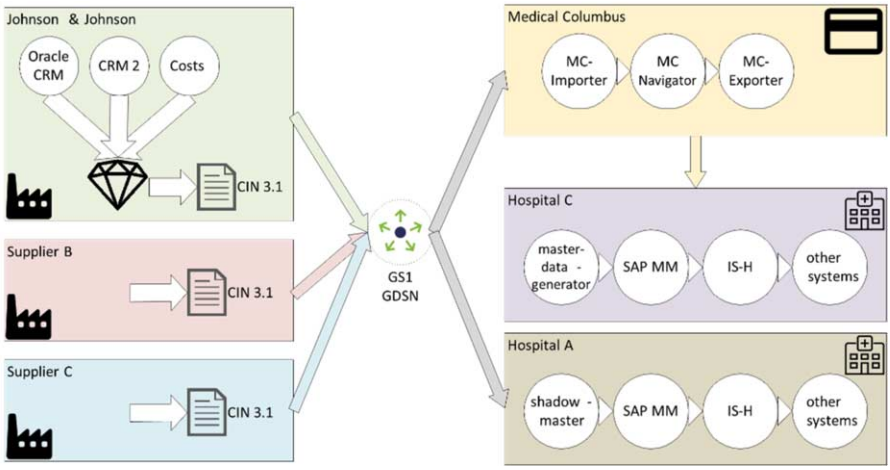

Figure 2. Desired future situation. Material master data is distributed over standard interfaces in a single format

4. Discussion

The technical conditions for an optimized maintenance of master material data catalogues do exist. Connection to the GDSN network either directly or via an EDI provider is possible and semi-automated update of the SAP MM master material data catalogue can be achieved. But the new version CIN 3.1 is not yet common place and the digital delivery of material master data is not a standard for small and highly specialized manufacturers in the healthcare area.

The process can be accelerated if hospitals put pressure on the supplier or manufacturer to adhere to the new standards, which can be reinforced if hospitals build

purchasing groups. The latter requires either synchronization of the eProcurement IT systems between the different sites or adoption of an EDI provider. Administrative regulatory pressure could be helpful, if supplier of healthcare goods do not apply these standards.

On the other hand, the manufacturers or provider incur considerable costs for the IT update which they will likely add to their sales prices. Connection to GS1 data pools results in costs as well for provider and for the hospital.

In summary, there is considerable potential for improving material data management in hospitals by defining automatable workflows based on existing standards, especially those stemming from the GS1 context. Using GTIN for article and package identification, the Global Location Number GLN, the Global Data Synchronization Network GDSN for exchange of material master data, and eCl@ss for highly-granular product classification allows to streamline and automate the whole material data workflow. There is, however, a lack of information regarding options and costs in hospitals, which should be addressed, among others, by more publications on this issue.

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4. Knowledge-Based IT Support

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Design Considerations for a Knowledge Graph: The WATRIMed Use Case

Borlli Michel Jonas SOME[a], Georgeta BORDEA[b], Frantz THIESSARD[b], Stefan SCHULZ[c,d], Gayo DIALLO[b,1]
[a]*Ecole Supérieure d'Informatique, Univ. Nazi Boni, Bobo Dioulasso, Burkina Faso*
[b]*Team ERIAS, BPH INSERM 1219, Univ. Bordeaux, F-33000, Bordeaux, France*
[c]*Institute for Medical Informatics, Med. Univ. of Graz, Austria,*
[d]*Averbis GmbH, Freiburg, Germany*

Abstract. The World Health Organization estimates that as much as 80% of the population uses Traditional Medicine (TM) in some form, and in particular, herbal-based Traditional Medicine (HTM). However, TM is mostly orally transmitted and suffers from lack of standardizations and lack of computable TM data. Shareable standards could enable computational support of TM data management. In this paper, we outline the design and development of the West African Herbal Traditional Medicine (WATRIMed) Knowledge Graph (KG), which is an effort for bringing West Africa TM to the digital world and help establishing bridges with conventional medicine. WATRIMed entities have been enriched with knowledge from external publicly available knowledge bases and further mapped with the BioTopLite Upper Level Ontology. As of result, the model of the publicly available KG currently comprises 472 Concepts and 75 Properties (57 object properties and 18 data properties). It describes formally 115 medicinal plants, 179 chemical compounds and 67 recipes.

Keywords. Plant based Traditional Medicine; Medical Knowledge Representation, Knowledge Graph, Upper Level Ontology

1. Introduction

There is an increasing consensus that medical knowledge representation (KR) should use shareable standards for enabling computational support of data management. The converging of tools and methods is opposed to the richness of domains, concepts, and especially domain terms in a multitude of languages. A broad account for health knowledge representation should therefore be able to formalize knowledge using the following KR assets as basic building blocks: a) Concepts (aka types, repeatables), i.e. language-independent entities of meaning that normally extend to classes of individual things; b) Individuals, i.e. tangible, non-repeatable entities; c) Terminologies, i.e. units of human language, denoting entities from a) or b).

Glued together by standardised languages (e.g. RDF, SKOS, OWL) and principles (e.g., linked data), the resulting propositions ideally result in shareable, interoperable, and computable KR assets.

Medical KR formalisms are especially challenged in domains that occupy a rather marginal position in the medical knowledge representation ecosystem. A typical example

[1] Corresponding Author: Gayo DIALLO, Univ. Bordeaux, INSERM BPH 1219, 146 rue Léo Saignat, F-33000, Bordeaux, France. Gayo.Diallo@u-bordeaux.fr

is traditional medicine (TM), which has a significant foothold in large areas of the planet, and which is intertwined with the most diverse cultural heritage of population groups, with large influence on the health status of a population. E.g., the WHO estimates that as much as 80% of the population uses Traditional Medicine (TM) in some form, and in particular herbal-based Traditional Medicine (HTM)[2].

The high usage of TM is often driven by the inaccessibility, unaffordability or unavailability of conventional health care services and medicines in socioeconomic settings that are characterized by a high rate of poverty and a lack of suitable and affordable conventional medicine services and drugs. That underserved and mostly illiterate rural people account for the majority of the population, is an additional barrier that makes access to healthcare difficult. In response to the growing recognition of the potential of traditional medicine, the supra-national West African Health Organisation (WAHO) has given priority to traditional medicine in 2007, with the objective of supporting the institutionalization of African Traditional Medicine (ATM) in member countries' health systems, followed up by WAHO's 2016-2020 Strategic Plan. Within this plan, an important action item is the standardisation of descriptions of herbal and traditional medicines in terms of the abovementioned KR assets. Together with the lack of computable TM data, it is difficult to take benefit from them for primary and secondary use cases: patient follow-up and public health statistics, phytovigilance about available herbal medications, etc. An important step was the launch of the first edition of the West African pharmacopeia in 2013, with inputs from ATM experts coming from different member states [1].

In this paper, we describe the design and development of the West African Herbal Traditional Medicine (WATRIMed) Knowledge Graph (KG). This effort aims at bringing West African TM to the digital world so as to help establish bridges with conventional medicine, similarly to previous attempts of digitalizing Chinese [2] and more general African TM [3][4], using a state-of-the art, flexible and shareable knowledge representation approach.

2. Material and Methods

The West African Herbal Pharmacopeia gathers information on medicinal plants used in West Africa, building on a first African Pharmacopeia including 105 plants created in 1985, followed by a book on medicinal plant analysis in 1986 [1]. It describes every plant by the following features: a summary description of the plant, its ethno-medicinal usage, related clinical information and safety, its chemical constitution, contraindications, the regions where the plant grows, a photograph, information on biological and pharmacological activity, and possible dosages and mode of administration.

With the goal of building a KG by linking the WAHO herbal pharmacopeia with TM knowledge, we identified the following set of publicly available Knowledge Bases (KBs), which allow to enrich the core information and to widen its scope while opening the perspective of wide-scale integration: DBpedia for plants and diseases; STITCH and PubChem for chemical compounds; IPNI for plants names and bibliographic references; GeoNames for information about countries and regions. It covers all countries with over

[2] Please see https://www.who.int/medicines/publications/traditional/trm_strategy14_23/en/

eleven million place names; Wikidata and Yago for local dialects and vernacular names of plants and recipes.

2.1. The WATRIMed Knowledge Graph building

The workflow to build the WATRIMed KG comprises three main components: i) Designing and feeding the TradiMed Database from the WAHO Herbal Pharmacopeia resources; ii) Designing the HTM Ontology, and links between TM and conventional medicine, which are particularly relevant for supporting phytovigilance activities and taking benefit from the advances in terms of pharmacovigilance and drug usage assessment in conventional medicine; iii) Mapping TradiMed and HTM Ontology and linking them to the external publicly KBs identified previously. We use for this the OpenRefine tool which allows querying external Web services and APIs.

Finally, each ontology unit is assigned human language names.

2.2. Mapping the HTM Ontology to a foundational (upper-level) ontology

In comparison with a domain ontology, a foundational (or upper level) ontology consists in very general categories that are common for a large set of domains. It contains entities that can be used to bridge the knowledge represented by domain-specific ontologies. Foundational ontologies can ensure the interoperability between different domain Ontologies. We have chosen to align the HTM Ontology with the BioTopLite2 Upper Level Ontology (BTL2), a light version of the BioTop Upper level Ontology for the Life Sciences [5]. BioTop has been launched in 2006 and described in OWL DL. For classes, BioTop inherits the top-level distinction of BFO [6] between the classes Continuant and Occurrent and between Independent Continuant and Dependent Continuant. The top primitive classes and relations of the new version of the ontology, BTL2, are shown respectively in Table 1 and Table 3. The upper classes and relations of WATRIMed are presented respectively in Table 2 and Table 4.

Table 1: BioTopLite2 upper primitive classes

Disposition	Process
Function	Quality
Immaterial Object	Role
Information Object	Temporal Region
Material Object	Value Region

Table 2: WATRIMed upper classes

Adverse Reaction	Therapeutic Action
Chemical	Plant Part
Component	Usage Precaution
Vocabulary	Formulation
Medicinal Plant	Vernacular Name
Recipe	ContraIndication

Table 3: BioTopLite2 (BTL2) upper relations

at some time	includes
causes	precedes
has condition	projects onto
has participant	represents

Table 4: WATRIMed main relations

has chemical component	has adverse reaction*
has therapeutic action*	has contraindication*
Has vernacular name*	has formulation
Information Object*	derives from

In Table 4, apart from 'has chemical component' and 'has formulation', all other relations (object properties in the OWL language) express dispositional statements instead of categorical ones.

The mapping process was done for all the concepts in Table 2 and categorical relations. It has been performed manually following a previous approach [7].

3. Results

3.1. The Herbal Traditional Medicine Knowledge Model and the WATRIMed Knowledge Graph

The Herbal Traditional Medicine knowledge model, referred as the HTM Ontology comprises 472 Concepts and 75 Properties (57 Object properties and 18 Data properties). The main component is the *MedicinalPlant* concept. It is linked with the *ChemicalCompound* entity by the object property *hasChemicalComponent*. A *MedicinalPlant* has a set of naming in different vernacular names. The *Moyatabél* vernacular name in Burkina Faso's Fulfulde of the plant *Alstonia boonei* is described with the following complex expression (we assume that wat is the prefix of WATRIMed and btl2 the BioTopLite2 one):

wat:*Moyatabél* **type of** wat:*'vernacular name'* and
(btl2:*'is part of'* some (wat:*Vocabulary* and
(btl2:*represents* value wat:*Fulfulde*) and
(btl2:*'is participant in'* some
(wat:*Usage* and btl2*:'is included in'* value wat:'*Burkina Faso'*) and
(btl2:*represents* only wat:*Alstonia_boonei*)

The following entities of the HTM Ontology have been linked to external resources identified among the external publicly available KBs: *MedicinalPlant*, *TheurapeuticIndication*, *ContraIndication*, *ChemicalComponent* and *Vocabulary*.

Currently there are 115 *MedicinalPlant* respectively linked to 100 DBpedia entities and 100 IPNI resources. Setting up these external links enabled to enrich the description of the plants, because the information provided by the two KBs is complementary. For *TherapeuticIndication*, about 40% of them are linked to DBpedia entities (42 out of 110). However, only 6 out of 110 could be linked to some Yago entity. Eighteen *ContraIndication* entities have been linked to Yago entities (12%). All the *ChemicalComponent* entities have been linked to external resources by fetching URLs from STITCH and PubChem. We have identified 13 out of 122 links for *Vocabulary* with Yago entities and 46% (56 out of 122) links with Wikidata.

3.2. The Mapping to the BioTopLite Upper Ontology

The mapping of the classes provided the following results, with respectively btl2: and wat: the namespace prefixes of BioTopLite2 and WATRIMed:

Simple subclass mappings was done for the following WATRIMed concepts: wat:*Adverse Reaction* under btl2:*process*, wat:*Chemical Component* under btl2:*compound*, wat:*Vocabulary* under btl2:*information object as well as* The wat:*Vernacular name*. The wat:*MedicinalPlant* concept is under btl2:*organism*, wat:*Plant Part* under btl2:*organism part*, and wat:*Recipe* is subclass of wat:*Therapeutic Mixture* which is under btl2:*compound of collective material entities.*

Complex subclass mappings are used for wat:*Recipe* and wat:'*Chemical Compound'*. Thus, for the wat:'*Acacia nilotica'* concept, we have the following expression:

wat:*Acacia_nilotica* **SubClassOf** (btl2:*'has part'* some wat:*'Arabic acid'*)
and (btl2:*'has part'* some wat:*'Chlorogenic acid'*)
and (btl2:*'has part'* some wat:*'Gallic acid'*)
and (btl2:*'has part'* some wat:*Leucoanthocyanidin*)
and (btl2:*'has part'* some wat:*3-beta-acetoxy-17-beta-hydroxyandrost-5-ene*)

No mappings for wat:*UsagePrecaution* and wat:*ContraIndication*.

The mapping of relations does not consider the dispositional relations. The WATRIMed relations are mapped as follows: the wat:*has chemical component* property is sub property of btl2:*has part*; wat:*derives from* is mapped as a subproperty of chaining properties (btl2:*has part of* btl2:*at some time* o btl2:*is part of*).

4. Discussion

For many people in Africa, Traditional Medicine either is the first line of treatment or is used as a last resort when all the available possibilities in the conventional medicine are exploited. Despite its affordability, it comes with various issues, in particular due to the oral transmission of knowledge and lack of digitalized resources that could contribute to improve the sustainability of experiences gathered. The WATRIMed initiative is the first large-scale attempt to overcome this issue in the context of West Africa. It benefits from decades of experience gathered by the West African Health Organization, which promotes and contributes to regulate TM usage among its member states. The aim is to provide a fully integrated digitalised and semantically explicit resource to the Linked Open Data cloud. We envision using WATRIMed to perform herb-drug interactions identification by performing graph completion. Some limitations of the choices made are discussed in the following sections.

4.1. Data Linking to External Knowledge Bases

The automated linking of the HTM instances (through the TradiMed Database) and entities from external, publicly available KBs relies on column names with a terminological similarity look-up. The matching to establish between two given entities depends on their lexical similarity, which could not be sufficient in case of synonymy for instance. This requires an in-depth human validation process. So far, we have manually checked the established correspondences. To illustrate the difficulty of the automated matching process, only 12% of the *ContraIndication* have been linked to external entities. There is a difference between the KB strategies in matching entities with OpenRefine: for instance, while for Yago it is quite strict (exact match), correspondences identification is more relaxed with DBpedia.

4.2. Linking to an Upper Level Ontology

There are several rationales for rooting a domain ontology in a foundational ontology. First, precisely defined classes and relations reduces the ambiguity of domain terms. In our case, "recipe" is placed under "btl2:*material object*", which precludes its interpretation as an information entity. Second, it precludes modelling errors: If "Recipe" were put under "btl2:*information object*" and linked with its material ingredients via "btl2:*has part*", it would contradict an upper level axiom. Third, ontologies that share a common upper level are more suited to be reused in other contexts. This is in line with the increasing characterisation of ontologies as standards (with SNOMED CT as example) and addresses the FAIR criteria for scientific data stewardship [8]. Fourth, building a new domain ontology as an extension of an existing foundational ontology speeds up ontology building and maintenance. Without an explicit foundational ontology, the authors would follow their own implicit upper level models, which heavily

depend on the use case and are often not sufficiently shared with those who have to use and maintain it. On the downside, there is a tendency towards more complexity, especially regarding nested axioms, which at least partly can be compensated by simplifications, e.g. by using new object properties as relation chains. Further simplification steps might be necessary when the ontologies are used in large KGs graphs, the performance of which might be affected by overly complex OWL models. This is one issue to be further addressed and investigated in WATRIMed.

5. Conclusions

We have introduced in this paper the first release of the West African Herbal Traditional Medicine KG, which is made available to the community at www.watrimed.org/wul.html together with a SPARQL endpoint. It could therefore be processed both by human and machines. It comprises 472 Concepts and 75 Properties. It is further mapped to the BioTopLite2 Upper Level Ontology and a set of external KBs including DBpedia, PubChem and GeoNames. It has been built from the core component of the WAHO's Herbal Pharmacopeia resource and linked to publicly available knowledge bases about plants, diseases and drugs. It is an ongoing work, which comprises currently 115 plants and 67 traditional recipes identified as treatments of common diseases in West Africa.

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An Extension of the Arden Syntax to Facilitate Clinical Document Generation

Stefan KRAUS [a,1], Dennis TODDENROTH [a], Philipp UNBERATH [a], Hans-Ulrich PROKOSCH [a], and Dirk HUESKE-KRAUS [b]
[a] *Medical Informatics, University Erlangen-Nürnberg, Erlangen, Germany.*
[b] *Philips Medical Systems, Böblingen, Germany.*

Abstract. While clinical information systems usually store patient records in database tables, human interpretations as well as information transfer between institutions often require that clinical data can be represented as documents. To automate document generation from patient data in conjunction with the rich computational facilities of clinical decision support, we propose a template-based extension of the Arden Syntax, and discuss the benefits and limitations observed during a pilot application for patient recruitment. While the original Arden Syntax supports string concatenation as well as the substitution of unnamed placeholders, we integrated an additional method based on embedding expressions into strings. A dedicated parser identifies the expressions and automatically substitutes them at runtime, which can for example be harnessed to display the most recent value from a time series. The resulting mechanism supports the generation of extensive clinical documents without the need to apply specific operators. To evaluate the proposed extension, we implemented an Arden module that identifies an intensive care patient cohort that conforms to the eligibility criteria of a clinical trial and outputs a concise patient overview in different document formats. While string interpolation in the original Arden standard has been tailored to clinical event monitoring, we interpret that our accessible approach usefully extends Arden's data-to-text capabilities. Future research might target the development of an interactive template editor that would hide the complexity of formatting directives and conditional expressions behind a graphical user interface, and explore how computer-linguistic formalisms might facilitate advanced features such as automatic inflections of verbs and nouns.

Keywords. Clinical document generation, Arden Syntax, string interpolation, natural language generation

1. Introduction

A clinical document can be defined as "a discrete electronic composition about an identified patient to be read or used by a human" [1]. Clinical information systems usually store electronic medical records (EMRs) in relational databases, where the corresponding clinical information is divided into entries in database tables. In order to support provider communication for a seamless clinical care, some parts of an EMR may be represented in the form of documents, such as transfer letters, consultant's reports, or radiology reports. To facilitate workflows between inpatient and outpatient settings, parts of an EMR may thus be converted to documents if required for information transfer

[1] Corresponding Author, Stefan Kraus, Chair of Medical Informatics, University Erlangen-Nürnberg, Wetterkreuz 13, 91058 Erlangen, Germany; E-mail: stefan.d.kraus@fau.de.

between departments or institutions, as in case of the Swiss electronic patient dossier [2]. Many clinical information systems provide their users with a means of generating documents, often based on a template system where data items can be inserted into document templates using placeholders.

In its intensive care units (ICUs), University Hospital Erlangen (UHER) uses a commercial patient data management system (PDMS) [3], which provides such an integrated template system using placeholders for the automated generation of documents, either in plain text, Microsoft Word, or in portable document format (PDF). The placeholders of this template system provide limited filtering and preprocessing capabilities, thus it is only sufficient for basic document creation. In use cases that require advanced document generation, however, this approach quickly reaches its limits. This motivated an earlier research on alternative means of generating clinical documents [4], which was based on the Arden Syntax for Medical Logic Systems, a Health Level 7 standard for clinical decision support functions in the form of Medical Logic Modules (MLMs) [5]. Although MLMs are originally designed for clinical event monitoring [6], they can be used for multiple other applications in the medical domain. The Arden Syntax provides a rich set of language constructs and a time-stamped data type system, which are both tailored to the needs of processing EMR contents for implementing clinical decision support functions. This study builds on the above mentioned earlier research and explores the capability of Arden Syntax to generate clinical documents, based on the integration of an extension for a template-based text generation, which is also called string interpolation. The technical platform constitutes an experimental generalization of the Arden Syntax, termed PLAIN [7]. There are two pronounced differences between the Arden Syntax and PLAIN with respect to this study. First, Arden Syntax MLMs generally correspond to condition-action rules. PLAIN, in contrast, additionally supports the use of Arden Syntax statements and operators apart from condition-action rules, thus providing a kind of medical informatics scripting language. Second, PLAIN supports the use of other MLMs as user-defined functions (UDFs) that can be called in arbitrary expressions.

Below we describe the characteristics of the proposed extension for string interpolation and its use in a real-world application at UHER, which generates documents for patient recruitment in a clinical trial. Moreover, we discuss the benefits and limitations of template-based document generation in contrast to ontology-based natural language generation.

2. Methods

The Arden Syntax standard provides three different approaches to compose text blocks from templates and expressions. The first one is the FORMATTED WITH operator ([8], 9.8.2), shown in Figure 1 A), which uses a variety of placeholders such as %s, %d, and %f, which themselves provide various flags to control the formatting. The second one is the string concatenation operator ([8], 9.8.1), shown in Figure 1 B), which is expressed with a double pipe symbol "||". The third one is the STRING operator ([8], 9.8.3), shown in Figure 1 C), which takes a list of expressions as the argument and concatenates the string representations of all elements to a single string.

```
A) WRITE (lastname, firstname) FORMATTED WITH "Patient: %s, %s" ;
B) WRITE "Patient: " || lastname || ", " || firstname ;
C) WRITE STRING ("Patient: ", lastname, ", ", firstname) ;
→ Patient: Mustermann, Max

D) WRITE "Letzter PCT-Wert: ${LATEST OF pct} ng/dl" ;
→ Letzter PCT-Wert: 12 ng/dl

E) WRITE "Patient: $lastname, $firstname" ;
→ Patient: Mustermann, Max
```

Figure 1: Examples A), B), and C) show the string interpolation approaches provided by the original Arden Syntax. Examples D) and E) show the additional approaches described in this study.

We integrated an additional string interpolation approach, which does not require the use of an operator to substitute the placeholders, but embeds expressions directly into strings. The substitution is automatically performed as soon as the control flow within an MLM reaches a string with placeholders. As a delimiter, we enclosed each expression with a pair of curly braces, prefixed with a "$" symbol. This pragmatic convention was inspired by the Haxe programming language [9], which also constitutes the technical basis of the PLAIN prototype, but is also used in a variety of other general purpose languages like PHP or JavaScript. To implement the string substitution with patient-specific values during runtime, we integrated a placeholder parser that analyses the content of the particular delimiter, accepts exactly one single expression, evaluates it, and immediately replaces it with the string representation of the evaluation result. Figure 1 D) shows a placeholder that uses the LATEST operator ([8],) and thus evaluates to the most recent value of the inflammation marker procalcitonin (PCT). In case the expression within a placeholder is a single variable name, the pair of curly braces can be omitted and it is sufficient to prefix the variable name with a "$" symbol, as shown in Figure 1 E).

3. Results

The proposed new approach enables the automated generation of extensive clinical documents through expressions that are directly embedded within string templates, without the need to apply specific operators. The substitution of the placeholders is automatically performed as soon as the control flow reaches a string, and may be used repeatedly in order to progressively assemble more complex textual outputs.

The method is currently evaluated in routine use at UHER since January 2019 in the context of a clinical study to identify a cohort of patients whose medications include specific antimycotics. For this purpose, an MLM retrieves the records of all patients that were admitted to three different ICUs as a single data structure, which is encoded in the PLAIN data markup language (PDML) [7], from a REST service connected to the data access interface of our local PDMS. The MLM then extracts those records where specific antimycotics were administered, and applies the string interpolation approach described in this study to generate a document containing an overview of all eligible patients.

```
WRITE @bold "Station: $ward, Aufnahmenummer: $case, Patientennummer: $patient";
WRITE "Aufnahme am ${@blue @gdate admission}, Entlassung am ${@blue @gdate discharge}";

IF EXISTS leukozyten THEN WRITE
   "Letzter Leukozytenwert: ${@bold @brown latest of leukozyten} /nl am
   ${@blue @gdate time of latest of leukozyten}";
ENDIF;

WRITE "Gabe von Antimykotika erfolgte ${@bold @brown count of antimykotika}
   mal über einen Zeitraum von
   ${@bold @brown ((last of antimykotika).admindate - (first of antimykotika).admindate)}";
WRITE @medlist antimykotika ;
```

Figure 2: Detail from the MLM that generates the overview of all eligible patients.

Figure 2 shows a detail from this MLM. It outputs either a HTML file to be displayed in a browser, or a PDF file to be stored on a network resource, depending on the requirements of the users. The identifiers prefixed with an @, such as @blue, are UDFs that are used for textual formatting. For example, the placeholder "${@bold @brown count of antimykotika}" calculates the number of antimycotics that were administered to the patient, and displays them in bold letters and brown color. Figure 3 shows a section of the document which is created by the code in Figure 2.

Station: M4, Aufnahmenummer [redacted], Patientennummer: [redacted]
Aufnahme Intensivstation am 31.12.2018 05:32, Entlassung am 14.01.2019 18:12
Letzter Leukozytenwert: **12.56** /nl am 13.01.2019 20:58
Gabe von Antimykotika erfolgte **3** mal über einen Zeitraum von **2 Tage 20 Minuten**
- **Anidulafungin i.v.** am 07.01.2019 17:40
- **Anidulafungin i.v.** am 08.01.2019 18:00
- **Anidulafungin i.v.** am 09.01.2019 18:00

Figure 3: Detail from the overview generated by the MLM.

4. Discussion

The string interpolation approaches provided by the original Arden Syntax standard have been tailored to clinical event monitoring, where textual outputs are usually of small size. In such applications, using one of the three operators in Figure 1 A), B), and C), is appropriate. For the generation of larger documents, however, the alternative approach described in this study proved beneficial in our local setting. Nevertheless, the code example in Figure 2 clearly shows that there is still room for improvements, as the mixture of WRITE statements, placeholders, UDFs, and IF Statements for conditional text elements may be still somewhat confusing. Thus, we will continue to further develop this still rather basic approach. Yet, even in its current state, this method clearly outperforms the capabilities of the PDMS' document creation tool and is well accepted by the users. As of now, documents generated with the method described in this study are only used for exchange between departments within UHER. As soon as a cross-institutional transfer should be intended, it would be reasonable to integrate support for encoding the documents on the basis of the Clinical Document Architecture [10] in order to augment them with metadata.

Integrating another approach to string interpolation requires additional skills from MLM authors, which may be seen as a disadvantage since it complicates a language initially designed for simple usability. Thus, it may be discussed whether some of the existing approaches may be removed. In fact, PLAIN does no longer support the FORMATTED WITH operator. A potential point of confusion for MLM authors might be the use of the $ prefix within strings. In Arden Syntax, variables are generally not prefixed. In the shortened notation, in contrast, a $ prefix is mandatory.

On a more general note, the string interpolation mechanism described above can be conceived as one of the many possible answers to the "data-to-text" problem for medical documents (see [11] for an overview). It implements a template-based approach to text generation, embedded directly into the source code. The obvious advantages of this approach, e.g. rapid development and low entry barrier for MLM authors, come at a price: The rigidity of the canned text phrases allow to cover only syntactically very uniform placeholder values. Also, if the data-to-text logic is, as it invariably will be once the desired output text reaches a nontrivial scale, distributed over many MLMs, maintenance will become a nightmare. This latter point, as well as the one mentioned earlier about the confusing mix of statements, expressions, and UDFs, could be addressed by another extension to PLAIN which could splice placeholder values into a more complex template which can be edited external to the MLM structure, hiding the details of formatting and conditional expressions in a "what you see is what you get" user interface, as outlined in Figure 4.

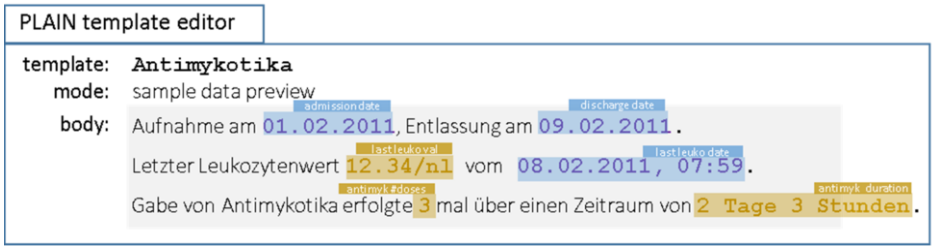

Figure 4: Outline of a template editor for more comfortable document generation.

However, if the output text becomes longer, more complex and narrative, simple templates will no longer be adequate. The need to create inflected forms of nouns, pronouns and verbs, the demand for conciseness, which in turn requires the linguistic machinery to "aggregate" various similar observations into a single more general one, the desire to vary the sentence structure and avoid uniform and monotonous "subject – predicate – object" main clauses and finally the necessity to refer to previously introduced entities with "referring expressions" (as in "the patient" – "Mr. Smith" – "he"), call for a radically different approach. The above mentioned linguistic desiderata for medical narrative text (see [12] for an overview) can be fulfilled by approaches from the area of "Natural Language Generation" (NLG). Approaches like Suregen-II [13], for instance, attach specifications of "how things are described" to an ontology of entities of a medical discourse domain. Data items from the PDMS or other clinical IT systems create instances of the respective classes which inherit these specifications, guided by formalisms developed by the area of computational linguistics. The tasks of aggregation, creation of referring expressions, inflecting verbs and nouns and of creating full, coherent

sentences is then fully carried out by the system. This way, users are freed from the burden of anticipating and caring for all the linguistic complications which make up a good clinical narrative. What's more, since the system uses an ontology, there is a high degree of reusability of already defined entities. For example, once it is specified how, to pick an evident example, a certain pain is being described using it facets of location/body area, quality, radiation, trigger and relief, this description can be reused in a large variety of clinical documents, from history and physical exam to a referring letter. Unfortunately, there are no NLG tools or systems commercially available which could readily support the generation of routine texts in the clinical domain.

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Swiss-Meds: An App Fostering Medication Adherence of Swiss Patient

Frederic EHRLER[a,1], Liliane GSCHWIND[b], Philippe MEYER[c], and Katherine BLONDON[d]
[a]*Division of medical Information Sciences, University Hospitals of Geneva, Geneva, Switzerland*
[b]*Pharmacy, Geneva University Hospitals, Geneva, Switzerland*
[c]*Division of Cardiology, Department of Medical Specialties, Geneva University Hospitals, Geneva, Switzerland*
[d]*Medical directorate, University Hospitals of Geneva, Geneva, Switzerland*

Abstract. Medication adherence is a widely recognized problem that is linked to overuse of healthcare system and negative health outcomes. Among the causes of non-adherence, forgetfulness plays a central role. mHealth interventions are particularly interesting to support medication adherence. Unfortunately, there is a lack of information about the quality and effectiveness of the app available on the market. In this article, we present the design and evaluation of an app for the Swiss market. The app was developed with a user-centered approach and was evaluated by both experts and end-users. The app functions include facilitated medication data entry through barcode scanning, and access to educational materials for specific drugs. Although the evaluation by experts and end-users revealed usability issues, such as the inability to customize the app, and a low evaluation of the performance (subjective assessment), it also found that the app contained most of the core functionalities that are expected for a medication adherence app. These are promising results, and will guide the future development of the app to respond to both experts and user expectations.

Keywords. Medication adherence, mHealth

1. Introduction

Medication non-adherence is a globally recognized problem. Poor adherence worsens clinical outcomes, induces higher downstream re-hospitalization rates as well as a higher use of resources [1]. Despite the physicians' efforts to convey the importance of the medications they prescribe, patients have many intentional and/or unintentional reasons for deviating from the treatment plan [2]. Prior research reports the most common factors associated with non-adherence: forgetfulness (50%), having other medications to take (20%), and being symptom-free (20%) [3].

The risk of deviation is further increased with the medication regimen complexity (MRC). MRC increases each time a patient is required to make a decision about taking medication [4].

[1] Corresponding Author, Frederic Ehrler, University Hospitals of Geneva, Gabrielle-Perret-Gentil, 4, 1205 Geneva, Switzerland; E-mail: Frederic.ehrler@hcuge.ch.

mHealth interventions are particularly interesting to support medication adherence. They can be used for instance to deliver education to patients, to collect data, to diagnose, to screen and to monitor patients, to offer treatment and behavioural change support, as well as to facilitate communication between patients and health professionals [5]. Apps can be used to improve medication adherence by sending regular reminders to the patients, to reduce forgetfulness. A meta-analysis of text messaging interventions to improve adherence to medication in chronic diseases showed that text message reminders were associated with increased odds of being adherent [6]. Although cost-effectiveness analyses of mHealth interventions are limited, a text messaging intervention in a population with CHD has been shown to be cost-saving [7,8].

Despite this plethora of medication adherence apps, there is still limited information on how they differ, the number and type of features they have, their overall quality, and their effectiveness [9]. Moreover, there are currently no apps that target the Swiss market with the available medications in this country.

In this paper, we report the development and early evaluation of the Swiss-Meds app using a tailored expert evaluation scale and end-user evaluation.

2. Method

2.1. Intervention design

To design our intervention, we listed app functionalities that could support adherence and avoid non-adherence. We selected the most interesting functionalities based on their frequency of reporting by end-users during a focus group. Then we started a user-centric design process involving specialists and end-users at each stage. In iterative cycles of requirement and prototyping, we conducted a sequence of focus groups with patients enrolled in a cardiac rehabilitation program. More particularly, one focus group was organized to test the usability of the medication summary. We also collected informal feedback from a larger patient population (up to 15 patients) on various topics (use of pillboxes and medication lists, perceived usefulness of history of administered medications, etc.) to optimize generalizability. We considered this additional feedback especially important for the health literacy issues, such as the simplified educational texts for medication side effects.

2.2. Intervention evaluation

Although several scales exist to evaluate the global quality of mobile applications for health, none are particularly developed with regard to medication adherence. Therefore, we used a tailored scale developed in a previous study to evaluate the quality of our app. It includes 30 criteria in 6 domains: security, privacy, quality of content, quality of information about the app, functionality, and esthetics and acceptability. A pharmacist assessed the app with this scale. We also recruited patients in a pharmacy to the app during 15 days, and then evaluate the app using the user version of Mobile Application Rating Scale (uMARS). This scale includes 26 questions in 6 domains: engagement, functionality, aesthetics, information and some subjective items. In order to promote the study, flyers were posted in the pharmacy and on the pharmacy website. The investigator invited all the pharmacy clients to participate in the study.

The inclusion criteria were: undertaking a chronic treatment (duration of more than 3 months), age over 18 years old, and owning a functional smartphone.

3. Results

3.1. Functionalities identification

Five patients (4 men, 1 woman) were recruited to help for the functionalities identification during a focus group. Guided by the domains of the MAR-scale, we discussed the potential functionalities that could help users to address the difficulties associated with adherence and selected the most relevant ones.

Table 1. Domains of the MAR-Scale and app functionalities identified to support each domain.

Domain	App functionalities
Management issues	Barcode scanning, medication images
Multiple medication	Global view on medication plan
Belief issue with medication	Information about medication adapted for patients
Availability issues	Reminders, also for refills
Forgetfulness and inconvenience issue	Timely notifications as reminders

Following the selection of the functionalities, we followed an iterative design process including rounds of prototyping of increasing complexity evaluated by a panel of5 end-users recruited at the hospital among the patients undertaking a cardiac rehabilitation.

In the final design of the app, the user begins with a summary of the current medication plan. Entering the medication plan is simple since the user can either scan the barcode on the medication box, or manually enter the additional medication to their list. A link to a Swiss medication database allows the auto-completion of drug name(s), active ingredient(s) and image(s) of the pills. Scanning the barcode on the medication box allows the user to retrieve all the information linked to the medication in the database, which can then be individualized (dosage, schedule, etc.). This provides a quick, efficient and secure method to create the medication summary. In the case of manual entry, the auto-completion provides existing options and combinations of drug name, dose and image for the user to choose from.

In the app, each medication has an associated image (from the database or taken by the user) to help ensure that the proper identification of the medication, particularly when multiple medications are administered at the same schedule.

Once the medication is entered in the summary, the user can set individual notifications for each medication to remind the user to take the medication at the right time. The application also computes the expected end of the medication box and thus sends a reminder to the user to get a refill.

To address the issues related to beliefs and comprehension about medications, we created educational materials for all the coronary heart disease-related medications, as well as for commonly used medications (ex: ibuprofen). These materials were adapted to the users' health literacy level, and tested with the users. We wanted to help patients acquire a better understanding of their medication, and to help them assess the implications of both adherence and non-adherence to their treatment. We particularly focused on the known side effects and the reasons for the treatment.

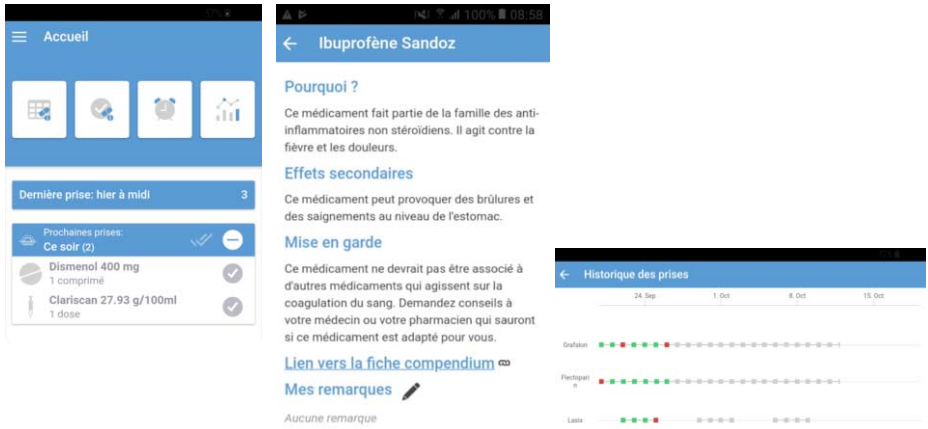

Figure 1. From left to right: main page of the Swiss-Meds application, information page on a particular drug and historic view of medication intake.

3.2. Expert evaluation

The evaluation by experts revealed that our app provides good quality regarding security and privacy, even if the user cannot erase their personal data when desired. Regarding the quality of the information in the app, the experts recognized the authors' expertise (cardiologist, pharmacist), but would have liked to have more details about the references and sources of funding. The quality of content is the dimension that can be improved the most, since no clear educational intervention is integrated in the app. For the functionalities, most of the core functionalities are present. An additional nice-to-have function was the adaptation to the time zone. On the aesthetic side, the capability to resize font as desired was lacking.

3.3. End user evaluation

After receiving an exemption from the ethical committee due to the qualitative outcome of the research, we recruited 4 participants. Recruitment of participants was complex since most of the visitors of the pharmacy (62%) did not have a chronic condition. The second factor hindering the inclusion of participants was the lack of interest (10%) and already having a solution (9%). In total, 3% of the approached patients were included in the study. The selected participants were 50% male and 50% female, aged from 20 to 59 years, and more than 50% of them had only one treatment. Three quarters of participants had an iPhone.

Table 2. uMARS evaluation performed by the 4 participants (each item ranges from 1= very bad to 5= perfect)

	Participant	**1**	**2**	**3**	**4**	**Mean**	**Sdt**
Engagement							
1	Entertainment	3	4	3	3	3.25	0.43
2	Interest	3	5	3	1	3	1.41
3	Customization	4	3	2	1	2.5	1.12
4	Interactivity	4	4	2	2	3	1.00
5	Target group	4	5	4	1	3.5	1.50
Functionality							
6	Performance	4	5	1	1	2.75	1.79
7	Ease of use	4	5	4	4	4.25	0.43

8	Navigation	4	5	3	4	4	0.71
9	Gestural design	4	4	3	5	4	0.71
Aesthetics							
10	Layout	4	4	3	5	4	0.71
11	Graphics	4	3	2	5	3.5	1.12
12	Visual appeal	4	4	2	4	3.5	0.87
Information							
13	Quality of information	5	3	2	4	3.5	1.12
14	Quantity of information	5	1	1	4	2.75	1.79
15	Visual information	5	4	2	4	3.75	1.09
16	Credibility of source	4	4	3	4	3.75	0.43
Total uMARS		4.06	4.06	3.94	2.50	3.25	3.44
Subjective items							
17	Would you recommend	5	4	1	4	3.5	1.50
18	How many times	5	4	1	3	3.25	1.48
19	Would you pay	3	3	1	3	2.5	0.87
20	Overall (star) rating	4	4	2	4	3.5	0.87

Evaluation of the app using the uMars scale after 15 days revealed interesting results. In general, except for a few items, the variance was pretty high. Two participants rated the mainly positively (more than 4 in the uMARS score), and two more negatively. The item that was judged as the most negative was the customization. Regarding the desire to pay, if 3 participants on 4 are open to the possibility of paying for such an app, none clearly expressed their willingness to pay. App performance was also judged negatively by two participants, who also that judged the app most negatively overall. On the positive side, app interaction as well as aesthetics was judged positively by all participants. Another positive side of the application was the quality of the information provided in the app.

4. Conclusion

Mobile apps have the capability to play a central role in fostering medication adherence. In this article, we present the development of Swiss-meds, an app designed with patients that includes functionalities such as a medication summary, simplified data entry through barcode scanning, and pill images for easier and better identification. It also provides literacy-adapted information about the medications, in particular for the side effects. The evaluation by experts and end-users revealed the good quality of the app, although the perception of users differed significantly.

5. Acknowledgments

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Intelligent Conversational Agents in Healthcare: Hype or Hope?

Kerstin DENECKE[a,1] , Mauro TSCHANZ [b], Tim Lucas DORNER [b] and Richard MAY [a]
[a] *Bern University of Applied Sciences, Bern, Switzerland*
[b] *Swiss Post Ltd., Bern, Switzerland*

Abstract. New developments in healthcare require an increased disease self-management of patients. Intelligent digital assistants equipped with a conversational user interface are intended to support patients in this challenging task by providing reminders, answering questions, or supporting in self-monitoring tasks. In this paper, we study the potentials of intelligent conversational agents in healthcare. We realized three systems for three different use cases (patient education, disease management, self anamnesis). Based on these implementations and experiences with usability tests, we performed an analysis of strengths, weaknesses, opportunities and threats (SWOT) using a questionnaire. The results show that conversational agents used in healthcare applications can be helpful. However, they have to be integrated into the healthcare process, supporting also the interaction between the healthcare team and a patient. In order to be attractive for a long-term usage, the scope of operation should autonomously adapt to the current health situation of a patient to provide relevant functionality as needed.

Keywords. Intelligent system, conversational agent, self-management

1. Introduction

Traditional models of care delivery basically base upon face-to-face interactions between clinicians and patients. The paternalistic model where the physician makes decisions for the patient is replaced by a collaborative model [1]. New technologies are augmenting this interaction model and fundamentally transforming the ways in which clinicians deliver care to individuals. The informed patient increasingly asks for applications that support in information gathering and that path the way through the health care system. Conversational user interfaces (CUI) in healthcare gained in interest in the last years, but it is still unclear whether it is just a hype or whether they are really useful. To address this question, we analyze in this paper strengths, weaknesses, opportunities and challenges of CUI towards their future implementation.

CUI or chatbots are programs designed to communicate with a user and to provide or collect information [12]. There are several mobile health applications available that are integrating CUI (e.g. CUI-based symptom checkers Babylon Health, or FlorenceChat). Further, this technology has been used in health related applications to achieve a health behavior change [2]. X2AI (https://www.x2ai.com/) provides mental health care, like cognitive behavioral therapy, in places where people would not

[1] Corresponding Author, Kerstin Denecke, Institute for Medical Informatics, Bern University of Applied Sciences, Quellgasse 21, 2501 Biel, Switzerland; E-mail: kerstin.denecke@bfh.ch

otherwise have access. Lokman and Zain introduced a chatbot that serves as a virtual dietitian for diabetic patients [3]. The chatbot asks questions and gives at the end a diet advice suitable for the current diabetic situation. The conversation is going along a path that is remembered by the system to consider all answers in the decision making. Only few CUI-based applications have been studied with respect to efficacy in clinical trials [4]. The objective of this paper is to identify challenges and opportunities of CUI in healthcare applications and to come up with a roadmap for the future development.

2. Methods

In previous work, we developed three CUI-based mobile health applications. They are using different technologies and consider various use cases. Given these experiences, the authors did the SWOT analysis.

2.1. SWOT analysis

SWOT analysis is a method to identify strengths, weaknesses, opportunities and threats. The idea of a SWOT analysis originates in strategic management research [13]. Adapting this to chatbots in healthcare, we consider strengths and weaknesses as features of the chatbots themselves, or 'internal' features. Conversely, opportunities include the economic, technical, social, political, legal, and environmental features representing the context within which the chatbots are implemented. We thus consider opportunities to be 'external' features. Threats are, similarly, external features that may prevent the real-world implementation of chatbots in healthcare. To determine the strengths, weaknesses, opportunities and threats of CUI in healthcare, the four persons involved in the development of three applications with CUI described below (eMMA, Ana, CLAIRE) were asked to fill the SWOT analysis questionnaire in Table 1.

Table 1: Questionnaire of the SWOT analysis

Strength	**Weaknesses**
- What is unique about our chatbots? - How skilled are the implemented chatbots? - What are advantages of the systems? - What are the greatest achievements of the three systems and what could be achievements in future?	- What needs to be avoided in the systems and their implementation in practice? - Is the knowledge base of the systems sufficient? - What needs improvement in the chatbots systems? - What disadvantages do the chatbots have?
Opportunities	**Threats**
- What external changes will bring opportunities? - What are the current ongoing trends in the field of medicine? - What is the market missing? Can chatbots provide the missing link to customers? - Are there changes in the field (technology) that are of benefit for the use of healthcare chatbots?	- What are negative aspects in the current market? - Will political instability impact the success of healthcare chatbots? - Is there a change in consumer taste to be recognized and considered? - What are obstacles to be faced when implementing the systems in practice and integrating them in healthcare? - Are there any standards, policies, legislation, government regulations changing that might negatively impact the success of chatbots?

2.2. Conversational agents Ana, eMMA and CLAIRE

The electronic medication management assistant *eMMA* assists a patient in managing his medication via a CUI [5]. The dialogue management is frame-based, i.e. the user is asked questions that enable the system to fill slots in a template in order to perform a task. eMMA provides the following functionalities: 1) reminder, 2) information provision on the current medication including food-drug interactions and information on the relevance of the medication, 3) intake schema of current medication, 4) collection of compliance data, 5) information storage on an eHealth Platform. The current medication is integrated into the app by scanning the barcode on the "eMediplan" [6].

Ana is a mobile self anamnesis application with CUI implemented for the field of music therapy [7]. Self anamnesis is a procedure in which a patient answers questions about the personal medical history without interacting directly with a doctor or medical assistant. Thus, Ana is asking questions on a patient's music biography which forms the basis for a music therapy. Ana's dialogue management is finite state, i.e. the user is taken through a dialogue consisting of a sequence of pre-determined steps or states. The knowledge base was created using the Artificial Intelligence Markup Language (AIML). Ana (1) asks the anamnesis questions and collects responses, (2) provides support when the question is not understandable to the user and (3) asks the user on the wellbeing status during the conversation. Responses in the chat are collected depending on the query by one out of four different formats: free text, two buttons, three buttons, and a 4-level-scale. For encouraging the user to complete the queries, the chatbot posts from time to time motivational statements.

The interactive smartphone application *CLAIRE* is a patient education system. The application combines virtual reality, a chatbot and a voice user interface (VUI). In a virtual environment the user can move freely, interact with objects and talk to the character Claire in order to learn about a specific health topic. CLAIRE uses gamification elements to motivate users [8]. The VUI is intended to establish a human-like conversation with the user. The chatbot is based on Synthetic Intelligence Markup Language (SIML). CLAIRE provides a frame-based dialogue management: it is in its current implementation able to understand questions on donation of personal health data formulated in different ways and by a variety of synonyms. All three systems are task-oriented and enable written or spoken input and output. Table 2 characterizes the three applications.

3. Results

The questionnaire was filled by four persons separately in November 2018. The results are summarized in the following.

3.1. Strengths

Chatbot technology has reached the point to lead a user through a predefined conversation tree. These conversations are suitable for specific tasks in healthcare where it is necessary to collect data from the user or provide information on a specific medical topic. Our three chatbots support in one specific task each (medication management, self anamnesis, patient education). This creates the possibility to

automate data collection (for example regarding symptoms, medical history, compliance) where the bot guides the user, step by step, through the conversation. The chatbot accompanies the patient and can make explanations upon user requests and user needs. In the dialog, a user can be motivated and encouraged with appropriate statements in exercising or measure health parameters etc. The communication establishes a human-like interaction in which a bond of trust is created between them. Users who trust the application are more likely to provide an honest answer if the chatbot asks about symptoms or on compliance regarding medical treatment such as drug consumption. A future system could integrate different scenarios. E.g. the patient first uses the system to make a self anamnesis. After the patient-doctor discussion and diagnosing process, the system gets additional information on the health activities to be supported (e.g. medication self-management, continuous health monitoring), a health goal could be set and specific educational material tailored to the needs of the patient could be provided. One strength is the flexibility regarding implementation and deployment of the chatbot: Our three chatbots are implemented as smartphone applications; CLAIRE could be also used on a desktop computer, facilitating the use together with family members. This enables the developer to tailor the deployment according to the end user preferences. By linking the conversational agents with eHealth technologies such as electronic patient records they can be integrated into the care process.

Table 2. Characterization of the three conversational agents Ana, eMMA and CLAIRE along the criteria of [4]

Criteria	**Ana [7]**	**eMMA [5]**	**CLAIRE**
Type of technology	Mobile device	Mobile device	Mobile device with VR glasses
Dialogue management	Finite state	Frame-based	Frame-based
Dialogue initiative	System	User	User
Input modality	Written / spoken	Written	Spoken
Output modality	Written / spoken	Written	Spoken
Task-oriented	Yes	Yes	Yes
Underlying technology	AIML 2.0	Rivescript 2.0	SIML 1.0
Use case	Self-anamnesis	Monitoring, medication management	Patient education
Year of development and phase	2018, Prototype	2017, Prototype	2018, Prototype
Evaluation	Usability test with 22 healthy subjects	Usability test with 10 healthy subjects	Usability test with 30 healthy subjects

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4.2. Weaknesses

Conversations with chatbots can become exhausting when the system does not understand or too many interactions are necessary. In contrast, when a user is familiar with a common user interface, he might be faster in realizing tasks or in getting information. The interest in interacting with the chatbot can drop over time. To avoid this, the underlying knowledge base has to be comprehensive. Our systems rely upon manually created knowledge bases to ensure that the provided content is reliable. A self-learning system, optionally based on a neural network as offered by OSCOVA[2], would be helpful, but a high quality of content has to be ensured.

Depending on the scope of the bot, the range of possible questions from users will vary. The developer has two options, either set a clear scope of the chatbot and try to lead the users through the conversations. This limits the dynamic in the conversations and the bot risks to be perceived as unintelligent. The other option is to widen the scope

[2] https://oscova.com/

(and thus have a large vocabulary and knowledge base) and let the users steer the conversations, which will increase the complexity of the chatbot as it has to understand a wider range of inputs. However, this can interfere with the core function of the bot and the prediction model will be less accurate. Hence, to create a robust chatbot the developer need to cover a wide range of expressions of the same intents to ensure the chatbot's precision. This phenomenon could also create another issue, that the chatbot understands the user, but replies using a different vocabulary than the one of the user.

4.3. Opportunities

Numerous functionalities can be added into conversational agents which creates flexibility. Tailored functions (reading QR code, accessing eHealth platform, retrieving data) can be triggered by actions from the chatbot to react to input from the users. Repetitive tasks like anamnesis collection, or patient education can be supported by the system and in this way support patient-doctor consultations: physicians can concentrate on the verification of the collected data, its analysis and interpretation. The development of eHealth infrastructures in different countries and the digitalization in healthcare offers the opportunity to combine mobile applications and to share data when needed. Not only can an eHealth system help chatbots and other healthcare apps to be successful. Those apps can encourage the user to use an electronic health record [11]. The demand on mobile applications to manage health data is increasing since other managing tasks can already be realized efficiently in mobile applications (e.g. eBanking). Current trends in healthcare target at connecting stakeholders, enabling interoperability. The healthcare market is missing simple and sustainable applications that can be used over a long period of time while staying interesting for the user and still provide benefits. Chatbots could address this issue, but would have to adapt functionalities and content over time, to fit with the changing health situation of a user and stay interesting. The increased interest in HL7/FHIR offers the possibility to consider standards in chatbots, which in turn contributes to interoperability. A future goal has to be to develop more intelligent conversational agents. Potentially, conversations with chatbots should come closer to those with real persons. This would allow patients to interact much more naturally with chatbots, e.g. based on a voice user interface. As a result, conversation barriers can be minimized and the acceptance of this technology significantly increased. Therefore, chatbots could become conversational assistants to support patients in a major part of the interdisciplinary treatment pathway.

4.4. Threats

Adopting conversational agents in healthcare can affect the patient-doctor relationship which relies on trust and the face-to-face conversation. A challenge is to get users interested in CUI-based healthcare applications, since several healthcare app are already on the market. While CUI-based applications are interesting at the beginning, they have to provide also benefits over time to compete other apps. Our applications depend on third party services such as Google Speech to Text within CLAIRE or the medication knowledge base integrated into eMMA. The quality of external services can threat the success of the systems. The healthcare domain is massively influenced by politics. When chatbot technology is claimed either by politicians or by physicians to be useless, inefficient, insecure etc. the technology will not be implemented comprehensively. There are several regulations that need to be

considered: data protection regulations, medical device regulations on a national and EU level, recommendations of the ministry of health etc. An integration with other healthcare IT systems is indispensable.

5. Conclusion

There are many use cases, where conversational agents are useful in healthcare. It can be assumed that they will play a leading role by embodying the function of a virtual assistant and bridging the gap between patients and clinicians [9]. The technical possibilities are still improving given the developments of artificial intelligence methods [10]. A substantial benefit is that in contrast to standard user interfaces, conversations can be tailored to the particular needs of a patient and to his health literacy. Finally, through communication, satisfaction and adherence to treatment regimens could be increased. Success story WeChat (www.wechat.com/en), a very popular Chines mobile application, points into a direction where CUI-based healthcare application should move in future. WeChat integrates instant messaging with a broad range of functionalities (ordering food, pay bills, search for jobs and people, book appointments with physician, play games…). Transferred to healthcare and considering the results of the SWOT analysis as well as from usability tests with the apps, the future roadmap should be: Limit the complexity of the conversations to interactions that are safe to be performed by a digital assistant. Possible tasks are scheduling appointments based on severity of symptoms, monitoring health status, reminding, and notifying nurses when parameters run out of control, offering comfort and support until the next appointment with the doctor. Further, we should not miss to integrate the systems into the care process which requires integration with eHealth and IT healthcare systems.

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5. eHealth and the Informed Patient (Young Researcher)

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Can the Austrian Nation-Wide EHR System Support the Recruitment of Trial Patients?

Gabriela AUGUSTINOV[a] and Georg DUFTSCHMID[a,1]
[a]*Section for Medical Information Management, Center for Medical Statistics, Informatics and Intelligent Systems, Medical University of Vienna*

Abstract. Automatic comparison of routinely collected EHR data with trial eligibility criteria can speed up patient recruitment. The present work aims to analyze to what extent the Austrian nation-wide EHR system ELGA could support this task. Using the open source tool ART-DECOR we tried to map a reference list of 150 common eligibility criteria specified in the EHR4CR project to the HL7 CDA templates that describe the structure of ELGA document types. For 61% of the criteria mappings could be made to ELGA template elements holding structured data. Comparing our results with similar work, we conclude that ELGA could be a useful component for the automatic identification of trial patients.

Keywords. Electronic Health Records, Clinical trials, Eligibility criteria, Patient recruitment, Austria.

1. Introduction

Due to the continuously growing volume of health data in electronic health records (EHRs), the latter have become increasingly attractive for various types of secondary use cases [1]. One such promising approach is to use EHR data to support the identification and recruitment of patients to participate in clinical trials [2]. Automated comparison of routinely collected EHR data with trial eligibility criteria can help to reduce delays, which typically result from manual patient recruitment [3].

Nation-wide EHR systems, which already exist in almost every second EU member state [4], represent a particularly attractive data source due to their potential to reach large patient cohorts. The present work aims to analyze to what extent the Austrian EHR system ELGA [5], which has been operative since 2015, could support the identification of trial patients.

ELGA (German acronym for "Electronic Health Record") can be characterized as a Shared EHR system according to [6]. It is based on an IHE XDS architecture [7] and enables a patient-centered documentation of medication data, lab reports, radiology reports, and discharge letters. All public hospitals, pharmacies, and outpatient panel doctors in Austria are obliged to participate in ELGA.

[1] Corresponding Author: Georg Duftschmid, Medical University of Vienna, A-1090 Vienna, Spitalg. 23, Austria; E-mail: georg.duftschmid@muv.ac.at.

2. Methods

In the course of the project "Electronic Health Records for Clinical Research (EHR4CR)" a reference list of 150 eligibility criteria was identified that are commonly used for the recruitment of trial patients [8]. We originated from this reference list and examined to what extent data for the contained criteria could be retrieved from the documents contained in ELGA.

ELGA documents are formatted according to the HL7 Clinical Document Architecture (CDA) standard [9]. The structure and components of the ELGA CDA document types have been specified as ART-DECOR [10] templates and are publicly available [11].

ART-DECOR is an open source tool suite that supports several steps in the implementation of a health information exchange (HIE) use case. The first step is the specification of high level informational concepts for which data should be exchanged. The second step is to identify existing or define new HL7 templates that describe the exact data exchange format. In order to specify the relation between the informational concepts and their pendants in the HL7 templates, the concepts can be formally mapped to template components in ART-DECOR.

The complete reference list of the EHR4CR eligibility criteria is available in structured form [12] within the medical data models portal [13]. Our first step was to represent each criterion as an ART-DECOR concept. This step was separately done by two students with a final harmonization of the results. Besides labeling concepts and logically grouping them, we had to map the 6 datatypes of the original list (Boolean, date, float, integer, string, text) to the more specific (Boolean, date, date/time, duration, quantity, decimal number, count, ordinal, string, text, code, identifier, binary, collection of data) ART-DECOR datatypes.

The ELGA document types are composed of a set of reusable "building blocks" that were specified as HL7 CDA templates at various granular levels and can be referenced within ART-DECOR from a so-called "building block repository (BBR)" [14]. Using the description of the ELGA document types in the ELGA CDA implementation guides [15] as well as the documentation of the templates in the ELGA BBR, we then searched for suitable pendants for each concept within the ELGA templates. Each such mapping was recorded as a so-called "template association" in ART-DECOR as shown in figure 1.

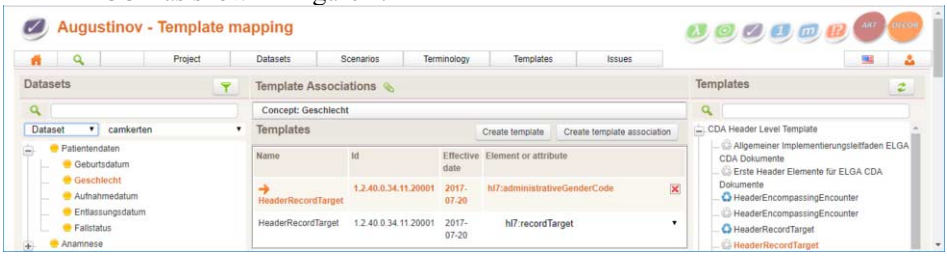

Figure 1. Mapping the EHR4CR eligibility criteria represented as ART-DECOR concepts (left) to ELGA templates (right) as ART-DECOR template associations (center).

3. Results

Originating from the 150 EHR4CR eligibility criteria, we created 148 concepts in ART-DECOR. Criterion "currently pregnant" existed twice in the original list and criteria "Leukocytes" and "white blood cell count" were assumed to be synonymous. We organized the concepts in the same 10 categories as in the original list and partly added more specific subcategories. All 81 criteria of EHR4CR datatype "float" (mostly used for lab findings) were mapped to concepts of the more specific ART-DECOR datatype "quantity". Three of 4 instances of "integer" were mapped to "quantity" and 1 ("pregnancy number") to "ordinal". Fifteen of 49 instances of "string/text" were mapped to "code", one ("currently breast feeding") to "boolean" and one ("heart rate") to "quantity". All other criteria were represented as concepts of the same datatype as the corresponding criteria.

We were able to map 90 (61%) of the 148 ART-DECOR concepts to ELGA template elements holding structured data (e.g., "birth date", "gender", "diagnosis code"), and 8 (5%) to elements of unstructured data (e.g., "diet", "diagnosis text", "procedure text"). Criteria that could not be mapped mostly related to the medical history of females (e.g., "currently pregnant", "menopausal status", "lactation") and to scores/classifications (e.g., "American Joint Committee on Cancer (AJCC) score", "Best-corrected visual acuity (BCVA) score"), which corresponds to criteria with low data availability in EHRs as observed in [16].

4. Discussion

The availability of patient data in EHR systems that may be used for clinical trials was analyzed by several authors before. Ateya et al. extracted eligibility criteria from 228 primary care studies from the UK Clinical Research Network Study Portfolio and came to the conclusion that 74% of the criteria could likely be fed by structured data from a typical inpatient EHR system [17]. Köpcke et al. examined local inpatient EHR systems of five German university hospitals for the existence of data for eligibility criteria from 15 randomly selected clinical trials [18]. They found that the EHR systems allowed data to be recorded for 55% of the criteria. El Fadly et al. focused on the reuse of EHR data to pre-populate trial data elements (not limited to eligibility criteria) and reported that 13.4% of the data elements of one selected trial could be fed by data from an inpatient EHR system of a French university hospital [19].

The before-mentioned articles analyzed institutional EHR systems for availability of data for trials, whereas we focus on a nation-wide inter-institutional EHR system. This has the advantage that (i) a larger patient cohort could be checked for trial eligibility, and (ii) trial criteria only need to be mapped to one single EHR data model instead of mappings to each institutional EHR data model [20]. As a limitation, a nation-wide EHR system must be expected to have a narrower coverage of data elements than institutional EHR systems.

Considering the latter limitation, ELGA's coverage of eligibility criteria seems surprisingly high, i.e. comparable with the institutional EHR systems of [17] and [18]. This might be explained by the fact that in [17] and [18] "raw" criteria of deliberately selected trials were mapped, whereas we used the common and simplified criteria of [8]. Further, the explanatory power of our results is limited insofar as we only considered the mere existence of the EHR4CR criteria within ELGA document types. We did not

have access to real ELGA documents and thus could not check to what extent the corresponding template elements are actually recorded. Even though the EHR4CR criteria are annotated with UMLS codes, we could not automate the mapping process as most fine-granular elements of ELGA templates are only textually described and lack terminological annotations.

However, with these limitations in mind, we still conclude that ELGA could be a useful component for the automatic identification of trial patients.

For full reproducibility of all details, we plan to publish the final results as a public ART-DECOR project that can be viewed with any web browser without additional software.

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The EU Falsified Medicines Directive A Concept for Drug Decommissioning in Hospitals

Sandra BURRI[a,1] and Rebecca SCHEIDEGGER[a]
[a] *Bern University of Applied Sciences, Biel, Switzerland*

Abstract. The EU falsified Medicines Directive 2011/62/EU will be applied in Switzerland as well. It mandates unique identifiers on medication packages and a process to ensure that these identifiers are decommissioned when the medication package is handed to the patient. While this is not a major problem for Swiss community pharmacies, it is yet unclear how decommissioning shall be managed within hospitals. This paper analyses the drug supply chain in 5 Swiss hospitals and drafts a system architecture to support a decommissioning process upon arrival of new drug deliveries at the hospital pharmacy.

Keywords. Medication process, IT support, hospital pharmacy, commissioning

1. Introduction

The European Union falsified medication directive 2011/62/EU from 2011 has been implemented to protect the EU from an increasing number of falsified medicinal products which reach the patients via the legal supply chain [1]. It has been supplemented with the commission delegated regulation (EU) 2016/161 [2] and amends the old directive 2001/83/EC from 2001 [3] to establish essentially the following mechanisms:

- Medicinal products subject to prescription shall bear specific safety features including a unique identifier (data matrix barcode) for the individual package
- Importers, manufacturers and distributors shall be registered with competent authorities.
- Member states shall provide national repository systems to ensure that falsified medicinal products can be detected and recalls be issued.
- These repository systems shall be interoperable with those in the other member states [1,2] using an exchange hub.
- Persons authorized to supply medicinal products to the public shall be obliged to decommission the unique identifier when supplying the product to the public.
- The marketing authorization holders shall ensure the decommissioning of the unique identifiers of recalled or withdrawn medicinal products.

The regulation shall come into force 9 February 2019 [2]. This implies that Switzerland, as an "associated" state, will establish a Swiss Medicines Verification System – SMVS, which will be connected to the European hub [4]. Swiss pharmacies or physicians, when

[1] Sandra Burri, Bern University of Applied Sciences, Quellgasse 21, CH2501 Biel/Bienne, Switzerland; E-mail: sandra.burri@students.bfh.ch

handing a medication package to the patient, will have to decommission the respective unique identifier.

Our activity centered around the question "How will Swiss hospitals deal with the task of decommissioning individual medication packages for their patients?"

2. Methods

2.1. Methods for analysis

The first part focused on an analysis of the current medication supply chain of five Swiss hospitals participating in the "Hospital of the Future Live" project [5]. We conducted semi-structured interviews with the hospital pharmacists, focusing on the order and supply chain from the retailer to the pharmacy and the drug commissioning and distribution process within the hospital to wards, clinics and departments. For feedback, the interviews were supplemented with follow up telephone calls and email communication. Workflows were translated into ARIS event-driven process chains (ePK) which were fed back to the respective hospital for verification. In addition, a comparative matrix of similarities and differences in the medication supply chain among the five hospitals was drafted.

2.2. Methods for defining the technical infrastructure and for mockup development

The second part comprised the recommendation of a future technical infrastructure for Swiss hospitals to comply with directive 2011/62/EU. Based upon the results of the analysis, six different options for the decommissioning of the drug package unique identifier could be identified. The five options within the hospital were discussed again with the pharmacists of the involved hospitals. It turned out that just one of these five options was acceptable for all 5 hospitals. Use case diagrams and a system architecture with all involved IT applications were drafted for this option. IT interfaces required for existing applications were identified and a user mockup was designed using Balsamiq and implemented using xampp with html, php and css.

3. Results

3.1. Analysis results

The participating hospitals had between 237 beds to 1'445 beds. A total of four workflow diagrams with some 20 activities plus associated roles, documents and IT systems were drafted, two for the external supply chain between wholesaler and hospital pharmaceutical depot, and two for the internal commissioning workflow between pharmacy and clinical departments. Two groups of hospitals could be identified. In a group of two hospitals (B and D) the ward dispensary is managed by a certified nurse who places drug orders for the ward at the hospital pharmacy and accepts the delivery of these drugs. The drugs are delivered by hospital transport services. The other three hospitals (A, C, E) have pharmaceutical assistants who manage some or all nursing wards. These pharmaceutical assistants are responsible for re-stocking of the ward dispensaries. They either deliver the drugs themselves to the ward or via the hospital transport services. In the latter case nurses are not involved in the drug order process.

All five hospitals agreed on the decommission of drug packages upon arrival in the hospital pharmacy; three hospitals would be able to establish checkout when drugs leave the pharmacy and two hospitals would be able to establish checkout when drugs arrive at the ward (see table 1).

Table 1. Options for the decommissioning of dispensed drug packages, five Swiss hospitals

Checkout	A	B	C	D	E
on arrival in pharmacy	ok	ok	ok	ok	ok
when delivering to ward	ok	ok	ok	rather no	rather no
when arriving on the ward	ok	no	ok	no	no
when preparing drugs on ward	no	no	no	no	no
when dispensing to the patient	hardly	hardly	hardly	hardly	hardly

3.2. Recommended technical infrastructure and mockup

Interestingly, all 5 hospitals used the SAP materials management system MMS for drugs. Thus, a generic system architecture (fig 1) could be drafted for option one from table 1 (checkout of the unique package identifiers upon arrival of drugs in the pharmacy).

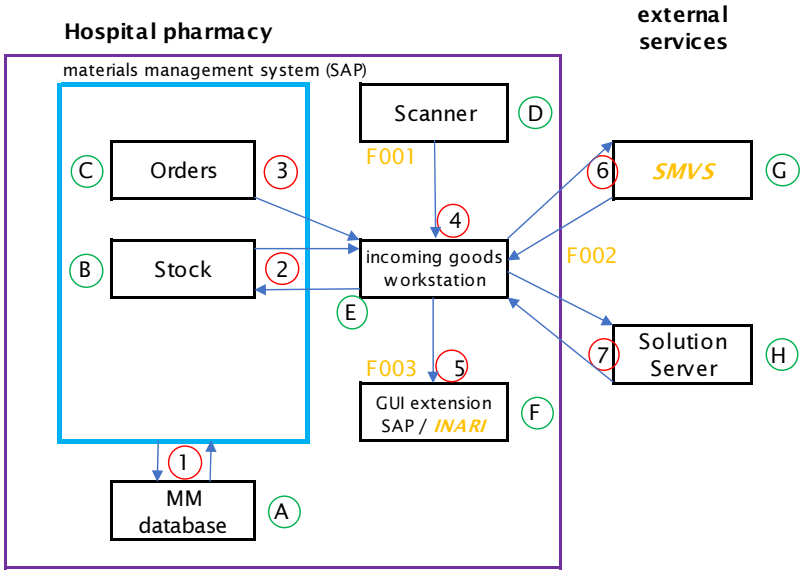

Figure 1. Proposed system architecture. Blue existing materials management system with database (A), in stock information (B) and order information (C), connected to one or more workstations with scanner (E, D) at incoming goods receiving area. Required new functions and components in yellow. F001: Scanner must be able to read new unique identifiers. F002: Scan workstation respectively material management system must communicate with SMVS for decommissioning. F003 User interface extension must be provided to display results of SMVS checkout process.

The SAP MMS could be supplemented with additional functionality either from SAP itself or a third-party supplier to enable the decommissioning of drug packages from SMVS. The scanning workstations at incoming goods need added functionality to scan the GS1 data-matrix of the drug package unique identifier (F001). This can be a new

functionality of the existing MMS or a separate application. F002 interfaces with the SVMS to decommission the unique identifier for each scanned package. A GUI extension must be either added to the MMS or implemented as a plugin to display results of the decommissioning process (F003). Drug packages which couldn't be successfully decommissioned may not be added to stock. These drug packages cannot be accepted by the hospital pharmacy.

4. Discussion

A Medline search for "hospital pharmacy commissioning" delivers a mere 28 hits and none relates to IT support for the process. There is one Polish paper [7] that discusses the effects of directive 2011/62/EU upon the Polish pharmaceutical industry and Polish pharmacies and emphasizes that "introduction of the FMD in Polish hospital pharmacies will be more difficult than in community pharmacies".

Our partner pharmacists stated that they order up to 95% of all drugs directly from the manufacturer. Thus, they think that essentially the risk of delivery of falsified medications is considerably lower compared to e.g. public pharmacies selling drugs directly to the patient. Therefore, the questioned Swiss hospital pharmacists would prefer an option not described here, namely that the manufacturer himself does the decommissioning when delivering drugs to the hospital pharmacy. All examined Swiss hospitals felt currently unable to support drug decommissioning when dispensing the drug to the patient. This is a strong indicator that those hospitals have not yet achieved closed loop medication for all departments and wards, which would be necessary for this type of checkout. In addition, the patients are given individual doses (e.g. single pills), thus it would be unclear when to check-out the package itself.

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Does eHealth Literacy Impact Patients' Opinion on the EHR?

Nora MÖRI, Jeannine BÜRKI, Priscilla DE OLIVEIRA MATOS, Philippe DÜLLMANN, Guillaume FRICKER, Yannick GEHRI, Robin GLAUSER, Yann GUND, Cynthia HALLER, Sabine KILCHHERR, Andy LANDOLT, Luca LEUENBERGER, Lisa LÜSCHER, Nicole MÜLLER, Marco SCHWARZ, Thevian SINNAPPAH, Gausegan UTHAYATHAS, Joshua DREWLOW[1]
Bern University of Applied Sciences, Biel, Switzerland

Abstract. An electronic health record (EHR) will be established nationwide in Switzerland in 2020. Patients can decide on their own whether they open an EHR. It is still unclear what might influence the patient decision. For this reason, we performed an online survey among the Swiss population to study whether there is a lack of knowledge on the EHR which impacts the willingness to open a personal health record and agree to health data sharing. A questionnaire with 13 question was distributed in a period of 4 weeks. More than 1200 participants replied to the survey. The results were analyzed with statistical methods. There are correlations between some of the questions in our survey. We conclude that the willingness to open a personal health record directly depends on the trust into the enabling technology.

Keywords. eHealth, EHR, eHealth literacy, health care reform

1. Introduction

Health literacy describes people's ability to independently search for, understand and apply health information in relation to their own health. eHealth literacy refers to this ability when information is gathered through electronic tools [1,2]. The technological development provides new tools to access health information. For example, Switzerland is about to establish the national electronic health record (EHR) in hospitals starting in 2020 [3]. People then have to decide to whom they provide access to their health data. The use of electronic aids requires certain competencies and knowledge [4]. It is still unclear, how many people in Switzerland are aware of the advantages of an EHR. In addition, there is often a lack of knowledge about legal issues with respect to the EHR and use of personal health data once it is accessible in the EHR [3]. This study analyses the current opinion on electronic health data sharing and the EHR. Therefore, we ask the following question: Can the acceptance in the Swiss EHR be increased through comprehensively communicated knowledge? Based on the question, we defined our hypotheses: 1) An informational video has a positive effect on people's viewpoint on health data sharing. 2. There is a correlation between lack of trust in electronic health data protection and skepticism about the EHR. To verify these hypotheses, we performed a survey among the population in German-speaking Switzerland.

[1] Corresponding Author: Kerstin Denecke, Bern University of Applied Sciences, Quellgasse 21, 2501 Biel, Switzerland; E-mail: kerstin.denecke@bfh.ch

2. Methods

Bachelor students of medical informatics at the Bern University of Applied Sciences realized this survey. The questions based upon the questionnaire of the Swiss eHealth Barometer that aims to analyze the perception of current developments in the field of eHealth in Switzerland [4]. Our survey comprised 13 questions grouped in four topics: general healthcare system, EHR, digital data storage and data sharing. It contained questions with only one possible answer, multiple choice, Likert-type scales and one open-ended, voluntary question for feedback regarding the questionnaire itself. The Likert scale from 1 "disagree" to 4 "agree" was used. A pretest was performed to ensure that the questions are understandable and to remove redundant questions. The study was not designed to evaluate the knowledge about the Swiss EHR project. The questionnaire was distributed in Switzerland by all co-authors using the snowball system. It was sent to friends, families and acquaintances of the co-authors via WhatsApp, email or other digital media. In a second stage, the survey was distributed directly to institutions, e.g. companies or schools. Answers were collected in a period of four weeks from November 1 to December 4, 2018. No preference of gender, age or professional background was relevant for this study during the gathering of data. The inclusion criteria were German speaking subjects of legal age. Half of the co-authors distributed the questionnaire attached with a video, while the other half distributed it without video. The video introduces how security is ensured in the context of the EPD (https://www.youtube.com/watch?v=7JMhAIbUNdU). It is provided by eHealthSuisse, the national organization for coordinating eHealth projects. In this way, we got replies from two groups of persons, one that was watching the video before answering and the other group not watching the video. To be able to get significant results, 1200 survey answers were targeted. The collected data was analysed by descriptive statistical methods. To answer our hypothesis, we performed a statistical test to show the differences between the two groups. The statistical test was a two-sided, unpaired t-test.

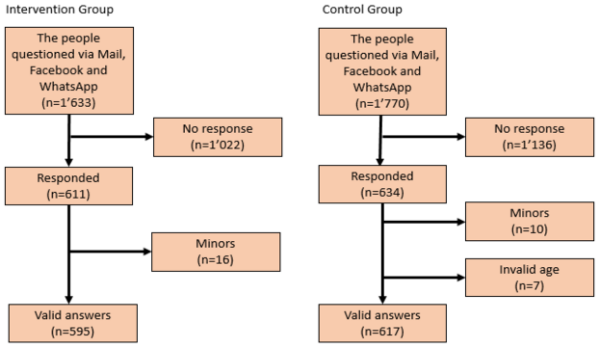

Figure 1: Response rate

3. Results

We received 1'245 answers, but had to exclude 33 questionnaires due to invalid age specifications. Thus, we considered a total of 1'212 valid answers. Figure 1 summarizes the response rate of our survey. The demographic characteristics in both groups are comparable. The main characteristics are shown in Table 1.

Table 1. Demographic characteristics

Variable		Control group (n=617)	Intervention group (n=595)
Female		311 (50.41%)	315 (52.94%)
Male		306 (49.59%)	280 (47.06%)
Age		32 (14.29%)	34 (15.5%)
Job			
	Administration	56 (9.08%)	55 (9.24%)
	Construction and architecture	52 (8.43%)	30 (5.04%)
	Finance	44 (7.13%)	42 (7.06%)
	Healthcare	130 (21.07%)	171 (28.74%)
	Information technology	77 (12.48%)	54 (9.08%)
	Management	32 (5.19%)	39 (6.55%)
	Sales	36 (5.83%)	46 (7.735)
	Industry and mechanic	43 (6.97%)	39 (6.55%)
	Other	147 (23.82%)	119 (20.00%)

Table 2. Demographic characteristics [mean (standard deviation)]

Questions	Control group (n=617)	t-Test p-value	Intervention group (n=595)
1. I am interested in health care	3.13 (0.89)	0.061	3.22 (0.88)
2. Have you ever heard of the EHR before?	342 (55.43)	-	323 (54.29)
3. I am in favor of the introduction of the EHR	3.17 (0.81)	0.31	3.12 (0.81)
4. I myself would open and use an EHR	3.08 (0.90)	0.737	3.07 0.87)
5. I would be willing to pay for the use of an EHR	1.93 (0.96)	0.16	1.85 (0.90)
6. I would agree that my health data is stored electronically	3.15 (0.88)	0.034	3.04 (0.93)
9. Health data on paper are well protected against misuse	2.47 (0.93)	0.022	2.35 (0.90)
10. Health data are electronically well protected against misuse	2.39 (0.83)	0.896	2.40 (0.80)
11. How important is it for you to be able to access your health data from home?	2.61 (0.99)	0.64	2.63 0.94)
12. I would like to be able to decide for myself which health professionals can access my data	3.27 (0.90)	0.086	3.36 (0.83)
13. I agree that health professionals can access my treatment data across institutions (e.g. from hospital to family doctor)	3.25 (0.87)	0.0075	3.12 (0.93)

Question	Age	1	3	4	5	6	9	10
Age	1	0.160	0.030	0.020	-0.113	0.007	-0.138	-0.013
1	0.160	1	0.255	0.312	0.057	0.181	-0.064	0.028
3	0.030	0.255	1	0.718	0.172	0.663	-0.152	0.285
4	0.020	0.312	0.718	1	0.229	0.667	-0.125	0.321
5	-0.113	0.057	0.172	0.229	1	0.098	0.145	0.312
6	0.007	0.181	0.663	0.667	0.098	1	-0.146	0.324
9	-0.138	-0.064	-0.152	-0.125	0.145	-0.146	1	0.145
10	-0.013	0.028	0.285	0.321	0.312	0.324	0.145	1

Figure 2: Correlation intervention group

In Table 2, the mean value and the standard deviation per question are shown. Two questions asking for advantages of electronic health data storage and on concerns were omitted because the answer type was multiple choice. Three questions show a significant difference between the two groups (marked in green). Despite the informational video shown at the beginning of the survey, the attitude towards the EHR is almost identical in both groups. To detect the dependency between the questions, the coefficient of correlation was calculated. The coefficients are summarized Figure 2 and Figure 3.

In the intervention and the control group, the same questions showed a coefficient that was over 0.5. This proves that there is a connection between the variables. There are three questions that have a dependency among each other. Therefore, we conclude that someone who supports the implementation of the EHR is rather going to open one and rather accepts the electronic storage.

Question	Age	1	3	4	5	6	9	10
Age	1	0.073	-0.032	-0.020	-0.089	-0.081	-0.085	-0.024
1	0.073	1	0.292	0.321	0.156	0.248	-0.057	0.167
3	-0.032	0.292	1	0.743	0.271	0.607	-0.117	0.329
4	-0.020	0.321	0.743	1	0.287	0.580	-0.115	0.305
5	-0.089	0.156	0.271	0.287	1	0.205	0.163	0.446
6	-0.081	0.248	0.607	0.580	0.205	1	-0.135	0.331
9	-0.085	-0.057	-0.117	-0.115	0.163	-0.135	1	0.159
10	-0.024	0.167	0.329	0.305	0.446	0.331	0.159	1

Figure 3: Correlation control group

4. Discussion

The results only partially confirm our hypothesis. We can conclude that the informational video does not impacts the opinions. We assume, that in the video the benefits of an EHR were not addressed clear enough, and our questions were to unspecific. The correlation found between certain questions confirms that the acceptance in electronic storage has a direct effect on the willingness to open a personal health record. This is not surprising since the confidence in a new technology is one of the basic elements of its success. In regard to relevance, it can be said that this survey with an average age of almost 33 years is representative for the younger part of the German-speaking population in Switzerland. For the older age groups, no reliable conclusions can be drawn from our survey. Finally, we conclude that for a successful introduction of the national EHR in Switzerland, it is of great relevance that the confidence of the population in relation to electronic data storage is gained. This confirms the statement of Norgaard et al. that the degree of eHealth literacy is significantly influenced by the complexity of the systems and the accessibility of electronic resources [6].

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6. Apps to Support Patients and Caregivers (Young Researcher)

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Improving and Evaluating eMMA's Communication Skills: A Chatbot for Managing Medication

Gabriel Immanuel HESS[a,1], Guillaume FRICKER[a,1], Kerstin DENECKE[a,2]
[a]*Bern University of Applied Sciences, Biel, Switzerland*

Abstract. In previous work, a mobile application for medication self-management (eMMA) was introduced. It contained a basic conversational user interface (CUI). In this work, we extended the CUI by integrating the chatbot framework RiveScript and an instruction interface. To study task success, dialog quality and efficiency, we performed a theoretical and a quantitative evaluation as well as a usability test. The results show that the technical extensions of eMMA were useful to improve the chatbot's quality. However, the underlying knowledge base still requires substantial extensions before the system can be used in practice.

Keywords. Chatbot, medication self-management, mHealth, conversational user interface

1. Introduction

Many mobile applications exist for patients managing their prescribed medication. Within the "Hospital of the Future live" Project [1], the mobile application eMMA (referred to as eMMA 1.0) was introduced as an electronic medication management assistant for persons prescribed to medications within an age range between 18 and 85 [2]. The goal was to address the problems of improving patient's medication adherence and communicating medication data with health care providers, as well as serving patients as an educational source for drug information. Unlike other electronical medication diaries, eMMA uses a standardized format for medication data and is built with a conversational user interface (CUI) to simulate the interaction with a human assistant. A CUI is not only expected to be handled easier by elderly people, the assumption is that the illusion of interacting with an actual assistant could also improve medication adherence. eMMA 1.0 relied on a CUI with restricted knowledge base, only able to respond to several key words and a selection of drug names [2]. In this paper, we describe the extension of eMMA's CUI by integrating a rule-based chatbot engine and an extended knowledge base (referred to as eMMA 2.0) for improving the quality of the CUI. Furthermore, we conducted a three-stage analysis for evaluating these extensions. This analysis consists of a theoretical analysis using a feature checklist, a quantitative analysis evaluating chatlogs from test persons using eMMA 2.0 and a usability test.

[1] Contributed equally

[2] Corresponding Author: Kerstin Denecke, Berner Fachhochschule, Quellgasse 21, 2502 Biel, Switzerland, kerstin.denecke@bfh.ch

2. Methods

2.1. Chatbot implementation

To decide on a technology stack, different chatbot frameworks were evaluated. Criteria for the evaluation included: the capabilities of the chatbot service (in particular the ability of handling conversation context), the possibility of integrating it into eMMA 1.0 and the ability of working with medication data. Services running on external servers were excluded to ensure data privacy and continuous availability. Once a chatbot engine was chosen, the corresponding rule set that defines the system's knowledge base was defined. For this purpose, first user tests with six test persons, recruited from the author's personal background, were conducted, to clarify the weaknesses of the CUI of eMMA 1.0. All test persons had already made first experiences in using chatbots. In additional iterations, the rule set was extended.

2.2. Chatbot evaluation

The chatbot was evaluated in three stages. First, a theoretical analysis using the TRINDI framework was made to get a benchmark of the enhanced CUI. TRINDI is a checklist comprising 3 groups with 16 questions addressing a dialog-based system's competences [3]. The first group (9 questions) refer to the flexibility in dialogue handling. The second group (5 questions), addresses the overall functionality of the system. The third group (2 questions) deals with the system's ability of context awareness. The checklist was independently filled out by two of the authors, with the answering options of "yes", "partially", "in theory", "no" and "unknown", as suggested by [3]. The resulting checklists where compared, and divergences were discussed until consent was achieved.

For the quantitative analysis, eight logs from eMMA 2.0 were compared to five logs from the tests with eMMA 1.0, where one log was lost due to technical problems. The analysis was done along the categories suggested from the PARADISE framework [4], namely task success, dialogue efficiency, dialog quality and user satisfaction. While user satisfaction was measured by a questionnaire accompanying the usability tests, the other categories could be derived from transcribed conversation logs. In order to analyze task success, individual tasks were identified in the logs and graded successful (coded TRUE) or unsuccessful (coded FALSE). For dialog efficiency, the number of dialogue steps used to complete such a task was counted. Dialog quality was measured by two variables: 1) the systems answering time, and 2) the adequacy of the systems immediate reply.

Furthermore, a usability test of the CUI of eMMA 2.0 was conducted with a sample of eight test persons. Since these test persons were not prescribed to medications at the time of the test, a scenario was created for getting them in a context where a medication management assistant is applicable. For surveying and comparing user satisfaction among the two versions of eMMA, the questionnaire from the usability test of eMMA 1.0 was used, consisting of 12 questions that were answered on a Likert scale from -2 to +2. Thus, the questionnaire could be completed within a range from -24 to +24 points.

To put the results from the quantitative analysis into context, the test persons additionally answered a short survey to what extend they would tolerate the lack of task success, dialog efficiency and dialog quality from a chatbot in a medical context like eMMA.

3. Results

3.1. Implementation

The chatbot framework RiveScript was chosen for reasons of privacy, ease of implementation and availability of German language foundations. It was included into eMMA 2.0 using the RiveScript 1.19 node module as an interpreter, running directly on the device. This interpreter module works as a black box, generating an answer to a user utterance, based on multiple rules specified in RiveScript files. The knowledge base of eMMA 2.0 was built on multiple pillars: First, basic German language understanding was added by a static script from the ALICE chatbot [5]. The file written in AIML could be translated into RiveScript syntax and had to be adapted to be adequate for the context. Answering patterns with medication context were included in another RiveScript file, context-awareness in mind. These patterns are based on the knowledge of eMMA 1.0, but also include results from the first usability tests and were improved iteratively during the entire development process. The Specialty List (http://www.spezialitaeten-liste.ch), a list containing all drug names of approved medications in Switzerland, was parsed to the RiveScript syntax and imported into the chatbot as external knowledge.

Since the RiveScript interpreter has no direct access to the application's memory, a dynamic context file is generated at every launch of the chatbot service, containing for example the user's medication or the name of the general practitioner. Additionally, we implemented an instruction interface that allows the chatbot to control the application through the interpreter. Specific keywords in the returned text string are caught before the answer is displayed to the user and trigger the corresponding action, e.g. displaying the user YES / NO buttons instead of a free text answering field. Other use cases for the instruction interface are adding a medication to the plan or looking up medication details online. With dynamically generated RiveScript rule files and the instruction interface, we enabled a two-way communication between the application and the black-boxed RiveScript interpreter.

3.2. Evaluation results

The theoretical analysis with the TRINDI checklist shows that the implemented chatbot still has room for improvement. None of the sixteen checklist items could be answered with *yes*, five points are fulfilled *partially*. Four other features were assessed with *theoretically*, meaning that the RiveScript syntax would enable them, but not the current implementation. The remaining checklist items were evaluated with *no* (see Table 1). The most important failed item is if the system checks its understanding of the user's utterance and can thus react accordingly.

Table 1. Evaluation results of the TRINDI categories

	Flexibility	Overall functionality	Context awareness
Yes	0	0	0
Partially	2	1	0
Theoretically	4	1	1
No	3	3	1
Total	9	5	2

As Table 2 shows, task success and the adequacy aspect of dialog quality were improved within eMMA 2.0. The slightly slower response time can be explained by the more complex pattern matching given the extended rule base. The average number of steps to

complete a task went up within eMMA 2.0. Contrary to expectations, eMMA 1.0 achieved a slightly better user satisfaction, although both versions are in the center of the scale ranging from -24 to 24. The usability test showed that users were able to interact with eMMA 2.0 and successfully finish complex tasks that need to hold the conversation context over several messages.

Table 2. Results of the quantitative evaluation

	Task success	Dialog efficiency	Dialog quality (response time)	Dialog quality (adequacy)	User satisfaction
eMMA 1.0	7.7%	5.3 steps	20 ms	16.9%	2.6 pt
eMMA 2.0	62.4%	9.7 steps	20 – 50 ms	59.3%	-3.3 pt

For context, we asked our test persons in the usability test what percentages of task success or dialog efficiency and quality they would consider acceptable. The resulting 84.2% for task success and 74% of dialog adequacy could not been reached by either of the evaluated versions. Also, the regarded acceptable number of steps of four for a simple and up to 9.5 for a complex task was missed by eMMA 2.0. Unaltered response time was in the range of milliseconds for both versions. Early usability tests showed that these are considered too fast, leading the original developers of eMMA 1.0 to artificially slow down the answering speed to the scale of seconds, which was kept for eMMA 2.0.

4. Discussion

In this paper, we introduced a rule-based chatbot to enhance the CUI of an existing medication management application by internal and external context information. The technical extensions led to better values in task success as well as in dialog quality. It turned out that the extended ability for more complex tasks led to a poorer dialog efficiency. To address this, graphical user interface elements could be contextually brought up inside the CUI for quicker handling of complex tasks. In general, the evaluations and user test shows, that, besides fixing technical bugs, the eMMA 2.0 chatbot still needs an enhanced knowledge base and a better context management. This can be achieved with the existing technology stack, but needs massive enhancement of the RiveScript rule files, based on more conversation logs and possibly assisted by machine learning. The introduced instruction interface could also be used to implement a function that allows the chatbot react adequately when it can't understand a user's utterance. Once these extensions have been realized, eMMA 2.0 will have the potential of being released on the market.

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Automated Rating of Multiple Sclerosis Test Results Using a Convolutional Neural Network

Martin Eduard Birchmeier [a,1], Tobias Studer [a]
[a] *Bern University of Applied Sciences*

Abstract. This work concerns methods for automated rating of the progression of Multiple Sclerosis (MS). Often, MS patients develop cognitive deficits. The Brief Visuospatial Memory Test-Revised (BVMT-R) is a recognized method to measure optical recognition deficits and their progression. Typically, the test is carried out on paper using geometric figures which the patient should recognize and trace. The results are rated manually by a physician. The goal of this work was to digitize the BVMT-R and to support the interpretation of the test results using a machine learning (ML) algorithm. A convolutional neural network (CNN) was used to rate the drawings of a patient. As a result, the correct point value of the BVMT-R could be determined with an accuracy between 57 % and 76% based on a training set of 624 patient drawings obtained from 135 patients. These drawings had been previously physician rated to serve as a gold standard. In our experiment, we obtained reasonable accuracy above 80% when more than 40 drawings were available, but our training sample was too small for more detailed analysis. Conclusion: At the currently achieved classification accuracy, results analysis will remain a physician task, potentially supported with ML based preclassification, but there is hope that ML accuracy can be further improved to enable automated follow-ups.

Keywords. Multiple Sclerosis, BICAMS, BVMT-R, Machine Learning, Convolutional neural network, digitalize

1. Introduction

Multiple Sclerosis (MS) is a demyelinating disease in which the insulating covers of nerve cells in the brain and spinal cord are damaged. MS causes inflammations in the brain as well as scattered occurrences in the spinal cord resulting in a range of progressively appearing signs and symptoms such as double vision, muscle weakness or coordination problems. It is the most common immune-mediated disorder of the central nervous system and can result in severe neurologic disabilities even in young adults [1]. The progressive cognitive deficits can be divided into domains such as information processing speed, attention function, learning/memory functions as well as executive functions such as planning and execution of complex tasks or problems [2].

In order to investigate these cognitive impairments, an international initiative was formed to recommend and support a fast and universal cognitive assessment named "Brief International Cognitive Assessment for MS" (BICAMS) [3]. The recommended test battery comprises three different tests, including the "Brief Visuospatial Memory

[1] Corresponding Author Martin Birchmeier, Bern University of Applied Sciences, Quellgasse 21, CH-2501 Biel / Bienne, E-mail: m.birchmeier@hotmail.com

Test Revised" (BVMT-R) [4].The BVMT-R test requires the patient to inspect a 2 × 3 stimulus array of abstract geometric figures. There are three learning trials of 10s time. The array is removed and the patient is asked to draw the array from memory, with the correct shapes in the correct position [3]. The test is carried out on paper and rated manually by a physician. Every correct draw of a figure in the correct place receives a rating of 2 points. If the drawing is not correct but similar to the original or correct but in the wrong position, the rating is 1. If the drawing is wrong or in the wrong place, the rating is 0 points.

The long-term goal of this project is the transfer of BVMT-R to a tablet based interface using an app and to automatize the results analysis using a machine learning (ML) algorithm. In this part we demonstrate the results of the automated analysis.

2. Method

We chose the "convolutional neural network" (CNN) technology for pattern recognition because this algorithm has been developed for visual object classifications [5,6]. The CNN analyses the images through a row of filters. The output of the CNN is a rating of the image with a probability-value for the reliability of the rating [7]. In our case the CNN was available on Microsoft Azure with the "Custom Vision" algorithm [8].

A total of 779 physician rated drawings from 135 MS patients was obtained from COGITO GmbH Germany. For each of the 6 BVMT-R figures between 127 and 134 drawings were available. All drawings were scanned and digitized with an app to adjust resolution, color and line width. The dataset was then random split in 624 figures (=80%) training and 155 (=20%) test drawings (see table 1).

For each of the six figures a separate CNN was trained.

Table 1. Accuracy of the rating of 6 ML algorithms (one for each figure) compared to the physician rating as a gold standard. n = number of test drawings, m is the number of drawings used for training.

Number	Figure	Rating 0	Rating 1	Rating 2
1	 (n=26, m=101)	0% *(n=2, m=5)*	67% *(n=6, m=23)*	83% *(n=18, m=73)*
2	 (n=25, m=102)	67% *(n 6, m=24)*	91% *(n=11, m=45)*	63% *(n=8, m=33)*
3	 (n=26, m=104)	67% *(n=4, m=26)*	63% *(n=10, m=31)*	67% *(n=12, m=47)*
4	 (n=26, m=102)	100% *(n=10, m=38)*	50% *(n=4, m=18)*	67% *(n=12, m=46)*
5	 (n=26, m=107)	88% *(n=8, m=34)*	50% *(n=6, m=23)*	92% *(n=12, m=50)*
6	 (n=26, m=108)	93% *(n=14, m=56)*	20% *(n=5, m=22)*	86% *(n=7, m=30)*
average	n=155, m=624	69% *(n=44, m=183)*	57% *(n=42, m=162)*	76% *(n=69, m=279)*

3. Results

Figure 1 maps the rating of the physician against the rating of the ML algorithm for all 6 figures. Dot size represents percent values. Diagonal green dots represent matching results of physician and ML rating. The green, top right point (2, 2), e.g. signifies that overall 76% of all drawings rated with 2 points were correctly classified by the ML algorithm. Thus, we measured an overall recognition accuracy of 69% for drawings rated with zero, 57% for drawings rated with one and 76% for those rated with two points (fig 1). Fig 1 also demonstrates that the likelihood of a gross misinterpretation (e.g. the ML

algorithm classifying a 0 for a drawing rated 1 or 2 by the physician) is small. The algorithm tends to rate drawings higher than they are.

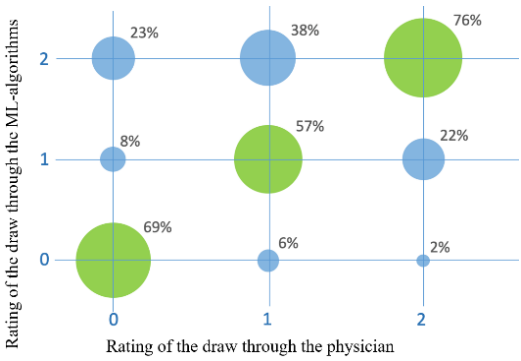

Figure 1. Classification by ML algorithms (y-axis) compared with the physician rating (x-axis)

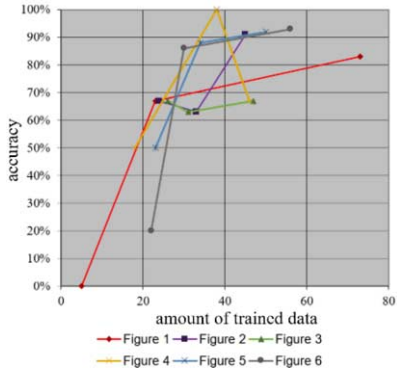

Figure 2. Number of training drawings per fig and the accuracy of the algorithm

Based on these results we were interested to determine the required size of the training data set to obtain reasonable accuracy of the ML algorithm classification. Fig 2 plots the number of training drawings per figure against obtained recognition accuracy for the 6 figures of the BVMT-R. For BVMT-R figures 1, 5 and 6 we note a strictly monotonic increasing plot. Figures 2, 3 and 4 are not fully monotonic. Achieved classification accuracy varies between 67 percent for figures 3 and 4 and 93 percent for figure 6. Good classification results start at 30 test drawings for figure 6 resulting 86% accuracy, closely followed by figure 5 (34 drawings resulting in 88% accuracy).

4. Discussion

We operated with a comparatively small dataset of between 101 and 108 drawings in the training set for each of the 6 CNN used in this experiment. This difficulty is common in medicine where it is not easy to obtain validated gold standard data for a certain problem, disease or finding.

Considering this fact, our classification results for the automated classification of the BVMT-R, although not brilliant, are encouraging. If a classification accuracy of around 80% can be achieved, it is conceivable that automated classification may be used as a first step in an IT based application to support the physician in his classification task. This is in accordance with Beam [9] who confirms that deep learning approaches, depending on the task, can be used even for small training data sets. It is an advantage that the BVMT-R figures are black-white only and comparatively simple.

BVMT-R figures 5 and 6 delivered better recognition accuracy, achieving more than 80% already with training data sets of 34 and 30 drawings, respectively.

We note that the ML algorithm has a problem to differentiate a semi-correct drawing (score 1) from a fully correct drawing (score 2) (fig 1). On visual inspection we can confirm that these kinds of drawings can often have small differences only, e.g. one extra line starting in the wrong corner of the rectangle.

Our future work, apart from the attempt to obtain additional physician rated training data will focus on the digitizing of the BVMT-R itself. It should be possible to represent the full BVMT-R workflow either on tablet or on another smart device. Obviously, we

will then need a patient study to compare paper based BVMT-R results with those measured with the digital device. We accept the possibility that there may be distinct differences in absolute values. The digitized test, however, offers the opportunity for repeated observations (using all 36 available BVMT-R figures) and thus to follow up the improvement or deterioration of a patient over time. At the currently achieved classification accuracy, results analysis will remain a physician task, potentially supported with ML based preclassification, but there is hope that ML accuracy can be further improved to enable automated follow-ups.

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An App to Improve Colorectal Carcinoma Follow-Up

Lukas WYSS[a,1] and Martin STIERLIN[b]
[a] *FMH - Swiss Medical Association* [b] *Federal Office of Public Health, University of Berne*

Abstract. Cancer is the second leading cause of death in Switzerland. Patients who have been diagnosed with colorectal carcinoma and received curative surgical R0-Resection frequently relapse or develop metastases in the first 2-3 years postoperatively. With timely detection through appropriate aftercare, some of these patients could potentially be cured. In order to optimize follow-up adherence, we implemented a study environment based on an app, which reminds patients to schedule their follow-up appointments timely with their GP or specialist. In addition, the study environment comprises a central server to collect pseudonomized study data regarding follow-up compliance. The next step will be a study to evaluate the potential impact of such an app. We present the outline of the planned study.

Keywords. Follow-up, mHealth, mobile application, colorectal carcinoma, patient adherence

1. Introduction

In Switzerland, cancer is the second leading cause of death, with particularly high mortality at an advanced age [1]. Demographic developments will continue to accentuate this [2]. The tumors of the lungs, colon, breast and prostate are those with the highest death rates in 2008-2012 [3]. If the cancer is detected early and resected completely, patients can be cured. However, in colorectal cancer, 30-44% of patients with R0-resection (no residual tumor) develop a relapse or metastasis, often in the first 3 years after surgery [4,5,6,7]. Therefore, good follow-up is essential [4,5,6]. For colon cancer a consensus recommendation of the Swiss Society of Gastroenterology (SGG) describes the recommended follow-up for colorectal cancer treated curatively by surgery [8]. There is evidence that IT-based clinical decision support systems (e.g. reminder) have impact on healthcare provider behaviour and in some cases also on patient outcome [9]. Against this background, the idea of an app to impact patient behavior for follow-up of colon cancer was born.

We describe the app which was directly designed in combination with a backend and database to support the evaluation of its impact on the patient and will discuss the planned RCT study design for this mobile application.

[1] Corresponding Author: Lukas Wyss, Berne University of Applied Sciences, Quellgasse 21, CH2502 Biel/Bienne, Switzerland, E-mail: wyslu1@gmail.com

2. Methods

We defined the use case of a patient undergoing colon surgery who may be willing to participate in a study examining the effect of reminder functions on his follow-up. Interviews were conducted with patients, physicians and the Swiss Cancer League to confirm the use case and to develop an appropriate user interface.

We designed a client server application with two different user interfaces, namely the follow-up app on a mobile device for the patient and the so-called GIST interface to support the patient enrolment into the study and the retrieval of study data. A shared normalized relational database model was designed for deployment on the mobile device using the LiteDB library for .net and on the GIST server using Flask-SQLAlchemy. The mobile app has been developed in C# using Xamarin for multi-platform deployment in combination with the Visual Studio IDE. Python 3.6 with the Framework "Flask" was used on top of an Apache 2 webserver for implementation of the server-sided software.

3. Results

The use case starts with the patient Hans, aged 72, who is diagnosed for colon cancer T1N0M0 and goes through hemicolectomy with curative intention. Post-surgery he is visited by a study nurse and asked if he likes to participate in the study. Upon signed consent the study nurse registers his case in the study database using GIST. GIST supports automated blinded randomizing to intervention or control group. It prints an enrolment scheme containing a QR code. The study nurse now assists Hans to install the client app TUNA on his mobile device. She helps him to scan the QR code which initializes the app for communication with the GIST server based on his unique study ID and which loads the appropriate follow-up scheme into the app. TUNA then reminds the patient for follow-up dates and requests confirmation that he made the appointment The following information is transmitted to the study server: completed appointments, deviation from target date of appointment, dropouts, quality of life value (scale of 1-100).

The applications (fig 1) consist of the TUNA mobile app and the GIST GUI running on a dedicated server. The mobile app TUNA (right-hand side) is to some degree independent from the GIST server and may be used as a standalone app by patients who do not want to participate. In those cases, the app can be initialized directly by entering TNM and surgery date and will then select the appropriate follow-up scheme.

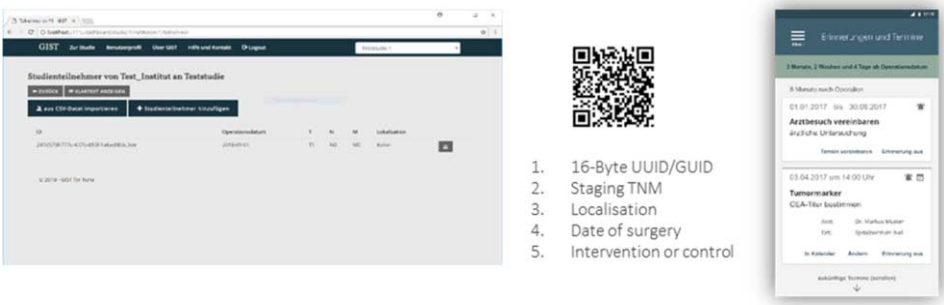

Figure 1. Left GIST server, one study patient opened for enrolment, in the middle printed QR code from enrolment sheet and its content, on the right TUNA mobile app with open reminder for CEA control.

In study mode, the TUNA app communicates patient data based on a unique study ID to the GIST server. This data can be evaluated regarding perceived and missed appointments, deviations from the target appointment date, dropouts and a subjective quality of life indicator.

4. Planned Study

Our goal is to examine the effects of the TUNA reminder app on follow-up adherence in an RCT study. The intervention to be examined is the reminder to the patient to make an appointment with his GP or specialist for the next follow-up. The hypothesis would be, that more follow-ups are made for a longer time period and in a timelier fashion if the patient uses the app. The planned study will be compliant to the «Clinical Protocol template for Investigator initiated trials» of *swissethics*.
Three options for the control group were under discussion:

1. The control group works without the app, they receive a piece of paper with the recommended follow-up scheme.
2. The app displays a PDF with the follow-up scheme on demand.
3. The apps reminder and appointment functions are deactivated.

Within the discussion another fourth option came up and has been implemented within the current design. Randomization is pretty visible to the patient and might influence him in options 1 and 2, whereas option 3 could be a problem for the ethics committee when control group patients have an obvious disadvantage.

Therefore, it is also possible to use the app with the full range of functions in the control group. In that case, however, reminders will be displayed at the very end of the recommended appointment period, i.e. 2 - 4 months after the optimal date, depending on the examination.

5. Discussion

The app and server side have been implemented but cannot yet been considered market ready. Thus, funding must be secured to achieve market readiness and to conduct the planned clinical study. In addition, the study will need a positive votum of an ethics committee.

The knowledge base for the reminders is restricted. The current implementation is limited to colon and rectal cancer. The SGG guideline [8] has concise follow-up recommendations only for the less aggressive tumor states, for complicated cases or patients with an M1 state the follow-up must be defined individually and thus cannot be implemented as a scheme. Other tumor types have been discussed, but, mostly, agreed follow-up schemes are either not existing or unhandy for implementation.

We are aware of the fact that we will need to follow a considerable number of patients over a long period of time (at least 2 years) in order to receive a valid measurement. This is a problem not only in terms of funding but also regarding drop outs, e.g. due to change of the living environment. Furthermore, the app and the GIST server must be maintained continuously for this time period despite potential upgrades e.g. in mobile devices operating systems which may change rapidly. Potentially, we have enabled the environment for multicentric recruiting of patients but intensive testing will be required for this functionality.

We will store sensitive patient data on the GIST server and may have to think about a split between patient identifying data and medical information in order to prevent attacks to the database. The chosen design took some care for this fact by defining the roles "Administrator" and "Registrar" on the GIST database. “Registrar” corresponds to the role of a study nurse and, after initialisation, presents only pseudonomized patient data. Patient identifying data and medical information are stored in different tables. They could also be stored on different servers.

Employing reminder functions has shown positive effects [9], but adverse effects such as alert fatigue and thus non-adherence are also well described [10]. We deal with a very sensitive patient group, patients with a potentially life-threatening disease, which may even get negative feelings when repeatedly reminded of their adverse situation and thus could develop a negative outcome. Therefore, we included a slider for the recording of a subjective quality of life into the app which is displayed every time a reminder pops up. We discussed more comprehensive QoL inventories but decided against it and in favour of a simple user interface and rapid user interaction.

Even if adherence to follow-up will be improved with the app, we cannot prove in the planned study design that this will improve patient outcome. Nevertheless, if such an app really reduces drop outs from patient follow-up, that might well be worth the hassle.

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A Mobile Application for Self-Monitoring for Patients with Heart Failure

Aaganya ARULNATHAN[a,1], Sayan VAAHEESAN[a,1], Kerstin DENECKE[a,2]
[a] *Berner Fachhochschule, Biel, Switzerland*

Abstract. Patients suffering from heart failure disease have to regularly measure and document health data such as weight and blood pressure. Currently, the data gets lost or is not recorded on a regular basis due to missing reminders and lack of motivation in patients. To address these problems, we introduce a concept for an electronic heart diary (EHD), a mobile application that supports in data collection and motivates the patient. The requirements towards a digital heart diary were collected in discussions with stakeholders in a collaborating hospital. The EHD, allows patients to record their measurement data or even transfer it from a health device to the app. The data is stored in a database that can be accessed with permission of a patient by health professionals through a web application for monitoring purposes. In this way, a worsening of the disease can be detected in an early stage and actions can be taken. This can increase patient safety and prevent rehospitalisation. For motivation and supporting a long-term use of the app, we included methods for gamification and nudging into the application.

Keywords. Self-monitoring, gamification, heart failure, cardiology

1. Introduction

Heart failure is a major and growing medical and economic problem worldwide as 1–2% of the healthcare budget is spent for the treatment [1,2]. The prevalence of heart failure has increased over the past decades and a further raise is expected due to the higher proportion of elderly in the western societies. The number of hospitalisations due to cardiovascular diseases increased in the last 10 years [1]. Besides the economic burden, heart failure disease significantly impacts the life of patients. According to the Swiss Heart Foundation, one of the most important interventions in this context is to prevent the disease from getting worse [3]. Although heart failure is a non-curable disease, lifestyle changes can increase quality of life and life expectancy of patients. Additionally, a continuous and careful monitoring of daily vital signs such as weight, or blood pressure allows to recognize changes or complications at an early stage, which in turn helps to take countermeasures [4]. For this purpose, patients have to carefully monitor their weight, blood pressure and symptoms, which is currently realized by a paper-based diary. Unfortunately, patients are usually not good at self-monitoring even with the support of healthcare providers [4,5]. They often forget to record their measurements in the diary or to bring the diary to the consultation with the specialist. This complicates check-ups and makes it more difficult to identify a worsening of the

[1] Contributed equally
[2] Corresponding author, Kerstin Denecke, Berner Fachhochschule, Quellgasse 21, 2502 Biel, Switzerland, kerstin.denecke@bfh.ch

disease. In this work, we address the question of how to improve patient's self-monitoring with the help of a mobile application. The main contribution is a concept for such applications. Beyond, we address the question how patients can be supported and encouraged in regularly measuring and recording relevant health parameters by means of the electronical heart diary (EHD).

2. Methods

This work is embedded in the "Hospital of the Future Live" project (SdZL) that targets developing IT solutions for future eHealth optimized health care processes [6]. For concept generation, we collected requirements by asking a cardiology specialist and a heart failure consultant from the hospital in Biel and Lucerne cantonal hospital for a description of the current situation and ideas on possible improvements. Furthermore, we contacted the Swiss Heart Foundation by e-mail to receive documents about heart failure, such as a heart diary and various information brochures. In order to gain a basic knowledge on self-monitoring and heart failure, we conducted a literature and web search mainly on PubMed and Google Scholar using the keywords "heart failure", "monitoring", "cardiology application", "gamification". The collected information was used to define a user story and use case scenarios. Finally, we developed our concept and implemented it in an iterative process as a native mobile application. Feedback of the specialists was continuously retrieved to improve the prototype. As a result of a literature search on the topics gamification and motivation of elderly people through healthcare applications, we decided for eNudging and gamification features to be integrated in EHD. This approach was evaluated in November 2018 by 30 persons at the prevention fair Expo 50+ in Zurich. The participants answered open and closed questions.

3. Results

The requirement analysis showed that the application should 1) support the patient in regularly recording specific health data and storing the values in a digital form in a database, 2) make the data available to the patients and the health professionals at any time, and 3) digitize the existing paper-based documents.

3.1. Electronic heart diary application (EHD)

EHD provides the following functionalities: 1) Collecting data on well-being, 2) entering measured values (weight, blood pressure and pulse), 3) reporting symptoms, 4) sharing health data with family members or health professionals, 5) providing collected data for clinical studies, and 6) providing contact details of health providers as entered by the user. The daily weight is an important value for the early detection of water accumulation in the body. Furthermore, measuring the blood pressure regularly is mainly relevant for patients where arterial hypertension causes the heart failure [7] and collecting the data improves the patients' adherence to the therapy [8]. In EHD, the user can record the weight, the systolic, diastolic value and pulse as measured by the corresponding devices (figure 1) either manually or via Bluetooth. To avoid mistakes in data collection, the app indicates what the user has to consider while measuring (e.g. that the weight should be measured in the morning after urination). Heart failure has a strong

effect on the physical and psycho-emotional quality of life [9]. However, within the treatment process, the well-being and quality of life of the patients remains often unconsidered, although this is regarded as an important predictor of mortality and re-hospitalization. The EHD app therefore asks every day for a judgement of the personal well-being on a scale of three (very good, well, not good). Further, the user is asked within the app for symptoms that can be selected from a list (e.g. pain, shortage of breath, loss of appetite). The application shows a summary of the measurement values of the current day and also provides statistics over a period of time.

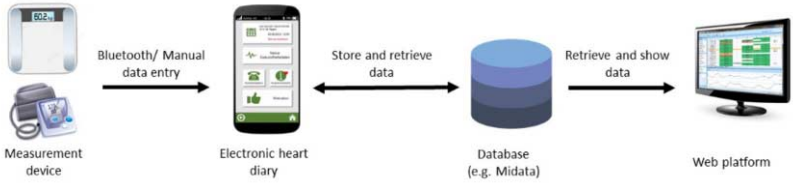

Fig. 1: Concept for the electronic heart diary

3.2. Concept for patient motivation

Most patients with heart failure are elderly people, constituting up to 80% of patients suffering from this disease with both incidence and prevalence of the condition increasing with age [10]. For this reason, we considered the question, how especially the elderly can be motivated to use our app. The social aspect is one of the most important factors that can have an impact on the elderly's level of motivation [11]. For this reason, our motivation concept involves relatives or friends who can create challenges through the app upon request of the user consisting of a goal and a reward (e.g. having a joint dinner). A challenge is for example to gain 20 points within a time period of two weeks. Points can be earned by entering values for weight or blood pressure. If the user forgets to record a measurement, he loses one point. The self-determination theory proposes three dimensions of human motivation: autonomy, competence and relatedness. When these three aspects are satisfied, a higher motivation level is reached, which in turns leads to technology adoption [11,12]. Our concept to motivate patients includes these three dimensions. Autonomy is fulfilled by allowing the user to decide whether he wants to involve a relative. The user strengthens his organizational competence by regularly entering the health data and accomplishing a given task. In this way, the user feels related to his loved ones which covers the dimension of relatedness. At the prevention fair Expo 50+, 30 participants took part in the evaluation. 23 persons were over 50 years and 7 persons under 50 years. 16 out of 23 persons (70%) older than 50 would use an app implementing our gamification concept. All persons under 50 consider including relatives and friends useful.

4. Discussion

Existing mobile applications for heart failure patients are mainly designed to support patient education. The app "Life with heart failure" provided by the Swiss Heart Foundation integrates a heart diary in addition to information on the disease [13]. In contrast, our approach integrates education, data collection and continuous monitoring. For the monitoring purposes, healthcare professionals require an application that supports in accessing the patient recorded values. Such application should be integrated

with the clinical information system to facilitate the interaction. We deliberately refrained from showing interpretations of the values within the applications. This will remain to be the responsibility of the physician. The application offers features for telemonitoring. Mobile telemonitoring is effective in reducing the risk of all-cause mortality and heart failure-related hospitalizations [14].

To the best of our knowledge, no other existing application offers an integrated motivation concept as we suggest. The evaluation at the Expo 50+ already showed that elderly people feel engaged by the challenge-feature of our app. In order to achieve higher acceptance, a larger scale study with heart failure patients has to be carried out to assess the usability of the application and to judge the success of the motivation approach. So far, a prototype of the application has been developed. A direct data transfer from digital scales or blood pressure measurement devices via Bluetooth still has to be developed. Here the Continua Design Guidelines can be used because they cover the entire technological range from a sensor to a document-based dossier [15].

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