Communication in Healthcare:

Opportunities for information technology and concerns for patient safety

Habibollah Pirnejad

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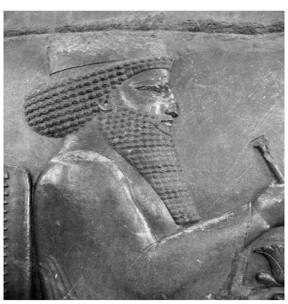

"The practice and study of medicine in Persia has a long and prolific history. The ancient Iranian medicine was combined by different medical traditions from Greece, Egypt, India and China for more than 4000 years and merged to form what became the nucleus and foundation of medical practice in the European countries in the 13th century."

(http://en.wikipedia.org/wiki/Ancient_Iranian_Medicine)

COMMUNICATION IN HEALTHCARE:
Opportunities for information technology and concerns for patient safety

Communicatie in de gezondheidzorg:
kansen voor informatietechnologie en patiënt veiligheid

Thesis

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Doctoral Committee

Promotors:	Prof.dr. M. Berg Prof.dr. R. Bal
Other members:	Prof.dr. J. van der Lei Prof.dr. J. Vissers Prof.dr. A. Hasman

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INTRODUCTION

1. Current healthcare communication

Advances in health science increased human knowledge about managing diseases and life threatening issues. They caused better health management, disease control, and extended longevity especially for handicapped patients and those with chronic disease, and accordingly change the demographic features and epidemiologic characteristics of society. Healthcare systems are now increasingly challenged with regard to managing chronically ill patients and those with multiple morbidity who need the collaborative care of different healthcare professionals [1]. However, an advance in medical knowledge also introduces more specialty and subspecialty domains into medical practice. And in an era in which healthcare services are set up around medical practice domains, a specialization trend results in healthcare organizations becoming more fragmented. Therefore, the current healthcare systems are making an inevitable migration from an acute to chronic-oriented and from centralized to decentralized care practices. Furthermore, healthcare professionals become progressively focused on their specialty domain, and speak to each other using domain-specific terms and jargons. Hence, it is difficult for professionals from different domains to understand each other. These factors contribute to the fragmentation challenge in healthcare, thus threatening the possibility of team work between diverse professionals, and making it difficult to provide integrated care for patients [2].

In recent years, many approaches and methods have been proposed to integrate the fragmented elements of patient care practices and to make them function smoothly [3, 4]. The core of every solution to meet the fragmentation challenge contains an effective system of communication between the stakeholders in patient care [5-7]. To furnish efficient and qualitative care, effective communication is required, especially for those healthcare organizations and providers that work on the same group of diseases or on the same group of patients [6, 7].

Nevertheless, healthcare organizations currently suffer from a range of communication deficiencies. Failure to communicate accurate, complete, and up-to-date information across interfaces in healthcare is a “major, avoidable risk to patient safety” [7]. Studies have shown that communication errors and failures in healthcare organizations account for a high rate of mortality and morbidity [8-17]. Poor communication, moreover, causes enormous inefficiencies in healthcare systems. Studies have demonstrated that considerable time and resources are wasted due to inefficient or problematic communication within and between healthcare organizations [14, 18-20].

2. Information and Communication Technology (ICT)

ICT[1] has considerable potential to improve healthcare communication and to respond to the growing demand for better and more efficient communication. It can resolve many of the above-mentioned problems and improve patient safety accordingly. Information technology can serve healthcare communication either *directly* or *indirectly*. In the direct form, for example, IT can provide reliable, fast, safe, and qualitative way for patient data to be exchanged between care providers within or between healthcare organizations [21]. In the indirect form, IT systems can improve communication: for example, by providing care professionals with patient-specific decision support advices suggestions that otherwise would have to be acquired through consulting other care professionals [11].

Despite all ICT potentialities, however, in practice the results have been far less to meet the expectations. To date, ICT has not fulfilled its promises, and its adoption by healthcare organizations has become a slow process [1, 22]. Thus far, information systems have either failed to be implemented in a number of healthcare environments or they could not achieve the implementation objectives [23-26]. Many of these failures are rooted in problems that these systems have posed to *intra-organizational* communication in one way or the other [27-29].

A major motivation for healthcare organizations to adopt and apply information technology has been the potential of these systems to improve the quality of healthcare and to reduce medical errors [30]. However, recent empirical studies have suggested that information systems can also contribute to error-inducing conditions in inpatient settings [27, 31-34]. ICT applications for improving *inter-organizational* communication have also been problematic [22, 26]. In the literature, integration problems of heterogeneous and mostly autonomous information systems have frequently been mentioned as a main reason for the failures in inter-organizational communication projects [35-37]. Therefore, although there is no doubt that ICT improves many aspects of healthcare communication and as a result benefits patient safety, it also generates problems and leads to errors in care practice. However, it is not entirely clear where and how an IT system causes these problems.

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[1] There is no universally accepted definition of ICT, since it is a constantly evolving era of knowledge. Throughout this thesis, however, we define ICT as 'all forms of computer and communication equipment and programming software used to create, store, transact, and manipulate all forms of patient data'. IT is frequently used instead of ICT, wherever we refer simply to computer systems and software programs.

3. Research question

In this thesis, we are keen to understand the dynamics between IT and healthcare processes that lead to unintended negative consequences of IT for patient safety. In other words, we would like to know: How can information technology be applied to improve intra- and inter-organizational communication in healthcare without jeopardizing patient safety? To answer the question, we choose to focus on medication data communication and the role that information technology plays in its improvement. There are four reasons for this choice: first, it is necessary for different care providers who are involved in a certain patient's care, to exchange medication data, regardless of how far from each other they are located geographically; second, a large number of medical errors involve medication, and ICT offers a promising solution [38-40]; third, medication data can easily be coded and registered in information systems, which makes it technically more plausible to be exchanged through information systems; fourth, the impact of IT on the medication process is a highly researched topic in the literature.

For the purpose of continuity in patient care, continuity in the flow of medication data between different healthcare providers and across different healthcare organizations is necessary. In other words, the flow of medication data within healthcare organizations (intra-organizational communication) has to be part and parcel of its flow between healthcare organizations (inter-organizational communication). Thus, in order to understand how ICT can properly be used to serve medication data communication at these two different levels, a cross-cut focus evaluation of intra- to inter-organizational communication is required. Figure 1 schematically represents the idea of continuity in medication data communication. Although the condition in real life is much more complex and involves more parties in the process, the figure represents in a simple manner how medication data communication is integrated at both the intra- and inter-organizational level.

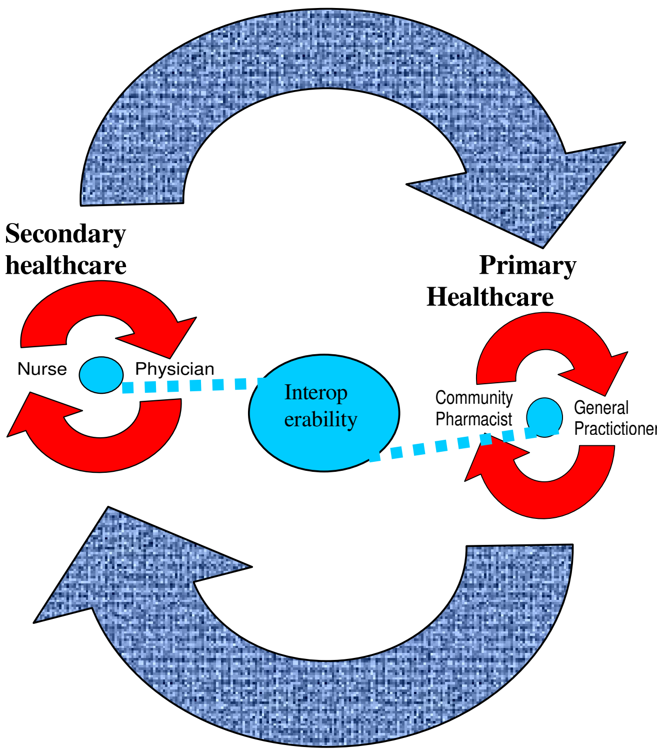

Figure 1. Relation of medication data communication at the intra- (small arrows) and inter-organizational level (large arrows). There must be consistency in the medication data transaction between and within healthcare organizations.

By focusing on the communication of medication data, the following sub-questions were defined to guide us throughout the research trajectory.

1. What are the dynamics in the healthcare environment that hinder the ability of ICT to improve intra-organizational communication and patient safety, and where are the possible solutions?
2. What impact does the implementation of a computerized physician order entry (CPOE) system have on intra-organizational communication, and what might be the negative effects of this impact on patient safety?

3. Which mechanisms of intra-organizational communication are affected by the implementation of a CPOE system, and what effect do impaired mechanisms have on the collaboration of nurses and physicians in medication work?
4. What are the main challenges to preserving interoperability in building an inter-organizational communication network through IT systems?
5. What are the challenges in building a large scale inter-organizational communication network for medication data communication, and how can theses challenges be met?

Each of the above research questions are elaborated upon and dealt with in a separate chapter.

4. Theoretical background

4.1. CONCEPTUAL FRAMEWORK

Our conceptual framework in this research includes two main interrelated concepts.

4.1.1. The concept of loop

The medication process is a highly collaborative one, within which healthcare providers must continue and complete each other's work. This requires a highly efficient system of communication, since a patient's data are handed over (e.g., during a shift change) from one care provider to the next, who has to update or change it, and then make it available for the subsequent care provider. In computer sciences and workflow management, whenever a process takes a circular form, a *loop* is defined to represent the interconnected and repetitive nature of actions within the process. Each action is connected to the next until the process is complete; the end result of the process can then be linked to the starting point of a different process or to the same process at another level. Drawing upon this, we consider the building of medication data communication using IT systems as the process of building a *loop,* whereby the medication work of different care providers is linked and integrated via communication processes [41]. Because the communication network needs to be interoperable (see the next topic), at its core this loop not only has to provide communicators with patient information but also has to contain "*norms*"[1]. These norms help to bind groups of care providers together and to build a mutual understanding of the exchanged information [41, 42]. If this loop is considered as a *closed* condition, *unclosed situations* represent the existence of breakdowns in the process and thus require redesign attention [41, 43].

4.1.2. The concept of interoperability

Communication is required for the necessary coordination and integration in medication work [5, 44, 45]. However, successful communication is not simply an information transaction process between communicators but is one that involves the usability of the exchanged information [27, 46, 47]. Usability requires the communicators to attain a more or less common understanding with regard to the information exchanged [48]. Therefore, consistency in medication work depends not only on a thorough information transaction but also on building a common understanding of the information exchanged [49].

The term "*interoperability*" is defined by the Institute of Electrical and Electronics Engineers as "the ability of two or more systems or components *to exchange* information and *to use* the information that has been exchanged" [50]. This definition has two components – information exchange and its use – and an information system is expected to have both. However, this notion is too idealistic with regard to current ICT. Recent studies have reported many inadequacies in the concurrent standards in covering healthcare communication processes, especially their semantic aspects [51]. Therefore, informaticians have now shifted their attention toward the usability of the exchanged information. They now further acknowledge the role that human need to play in interoperability construction. For instance, Charles N Mead, former Director at Large, Health Level 7[2] Board of Directors, defines interoperability as "the ability of parties**,** *either human or machine*," to exchange and to use data or information [46].

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[1] Norm refers to the principle of a right action binding upon the members of a group and serving to guide, control, or regulate proper and acceptable behavior [Merriam Webster Dictionary]. For more details about these norms, please see the Chapter 1.

2 HL7 is an organization involved in developing an international healthcare standard. It provides a framework and related standards for the exchange, integration, sharing, and retrieval of electronic health information (http://www.hl7.org)

Throughout this thesis, building interoperability concerning the data transacted between care providers is defined as “successful communication” and as the objective of an information system application to improve communication. On the basis of this understanding, interoperability lies at the center of every IT configuration regardless of whether it serves intra- or inter-organizational communication (Figure 2). An information system can only be expected to improve communication if in one way or another it advances interoperability among healthcare providers. It is not enough to improve the syntactic interoperability in medication data communication: the semantic interoperability is more important. Chapter 1 offers a detailed overview of the interoperability concept.

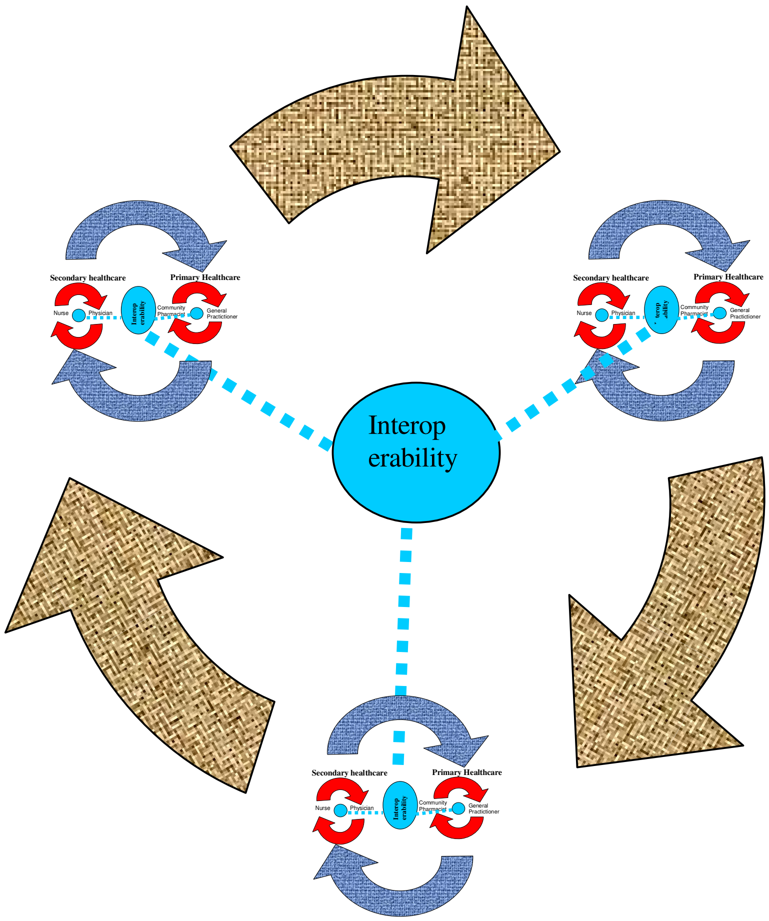

Figure 2. By moving from an intra-organizational to an inter-organizational level of healthcare communication, interoperability remains at the center of all healthcare communication events. Therefore, with the focus on the concept of interoperability, the subject of research can easily be moved from an intra-organizational to an inter-organizational level in evaluating the dynamics between information technology and healthcare work.

4.2. SOCIO-TECHNICAL APPROACH

The research design and data analysis in this thesis have been influenced by the socio-technical perspective. This view entails that organizations simultaneously consist of social and technical elements that are interdependent and interrelated. Healthcare organizations consist of people, values, norms and culture, and technologies. Without tools, equipment, procedures, technology, and facilities, people cannot work and the organizations would cease to exist and vise versa [22]. Organizational or social elements cannot be separated from technical elements, hence the term *socio-technical elements*. Instead, organization and technology are interwoven to form a socio-technical system [22, 52].

The implementation of ICT changes organizations with regard to norms, rules, relations, the work structure, staff behavior, attitudes, and so forth [53]. The effect of the implementation, however, is not a one-way process: the target organization also strives to adopt the implemented system and to customize it to its own need [54]. The ICT system's features and behavior will be transformed as a result of interactions between socio-technical elements. Accordingly, "good design or implementation is not a technical problem but rather one of jointly optimizing the combined socio-technical system" [55]. A problem, that might appear at first to be a technical may prove to be rooted in a socio-organizational issue or vice versa, if it is examined by means of a socio-technical approach [22, 53].

5. Methodology

The main research design for this study consisted of qualitative methods. However, quantitative methods were also applied to evaluate the impact of an IT system on intra-organizational communication. Among the qualitative methods, interviews with informant users, observations, and document analyses were used to collect data. The quantitative data collection methods consisted of two pre- and post-implementation surveys. A more detailed explanation of these methodologies is provided in each chapter.

As we were interested in the patterns of action and interaction between and among different socio-technical elements, we used *grounded theory* methodology to analyze the data. The perspectives of actors that were significantly relevant to the medication data communication were analyzed through a classic method of data coding, constant comparison, conceptual mapping, and interpretation. Our conceptual framework also served to combine quantitative and qualitative findings.

6. Thesis outline

Every chapter in this thesis deals with one of the research questions mentioned above. Chapter 1 serves as a theoretical underpinning for our empirical studies. It is an analytical literature review of diverse scientific disciplines related to inter-personal communication. It examines current healthcare-related intra-organizational communication problems that lead to errors in healthcare practice and it elaborates upon the dynamics between inter-organizational communication and standardization processes. Moreover, it discusses the possible roles and scenarios for IT to improve healthcare intra-organizational communication. The chapter closes by proposing methods to promote standardization and to advance IT application in healthcare.

Chapter 2 evaluates the impact of a CPOE system on nurse-physician communication. The effect of the system on building interoperability in the medication-related collaboration between nurses and physicians is assessed by both qualitative and quantitative methods. We deal with interoperability problems that have appeared in nurse-physician communication following the implementation of a CPOE system, and recognize many workarounds devised by nurses and physicians to solve those problems. We also discuss how the developed workarounds represent a considerable risk for patient safety.

Chapter 3 assesses the impact of a CPOE system on collaboration between nurses and physicians during their medication work, and compares it to a preceding paper-based system. Both quantitative and qualitative methodology was used to appraise and compare supportive and non-supportive features of the CPOE and the paper-based medication systems. We discuss how synchronization and feedback mechanisms between nurses and physicians were damaged by the implementation of a CPOE system, and examine how this impairment leads to communication problems and patient safety issues. At its close, the chapter makes recommendations with regard to repairing the damaged mechanisms and to adjusting the system's design.

Chapter 4 is a case study of the building of a regional inter-organizational communication network between primary and secondary healthcare for the exchange of medication data. The project was in an ideal situation with regard to technical elements. The ability of the project to preserve interoperability between primary and secondary care providers is analyzed in this chapter. The problems that the project faced concerning data integration and saving medication data integrity are analyzed. The chapter concludes with the observation that many of the problems are rooted in the lack of integration of work processes and in the way people work with the information system.

Chapter 5 looks at the challenges to building an inter-organizational communication network at a national level. Taking into account that interoperability is at the center of such a network, the chapter elaborates upon the major challenges for its construction. Drawing upon a socio-technical analysis of the challenges, the chapter concludes with advices and recommendations.

The empirical section of this thesis evaluates three projects: a CPOE system, a regional inter-organizational communication project (TUMA), and the Dutch national project of inter-organizational communication network for medication data. Although these projects appear to be highly successful, we do not elaborate upon their positive achievements. Conversely, considering the critical importance of patient safety, we look in detail at the projects' shortcomings and the conditions that threaten patient safety. In addition, we raise points that we hope will be useful for a safe ICT design and implementation in healthcare.

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CHAPTER 1

Intra-organizational communication in healthcare: consideration for standardization and ICT application

Habibollah Pirnejad, Zahra Niazkhani, Marc Berg, Roland Bal

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Abstract

Objectives: Intra-organizational communication is mostly interpersonal. Synchronous interruptive communication is recognized as a primary source of inefficiency and error in healthcare, and there is much potential for Information and Communication Technology (ICT) to improve such communication. As recently suggested, however, due to communication failures ICT can also compound medical errors. In this paper we analyze factors that restrict the role of ICT in improving interpersonal healthcare communication and suggest solutions.
Methods: We critically analyzed the literature from a selection of diverse scientific disciplines. These were related to interpersonal communication, to the role and place of standardization and computerization in its improvement, and to reducing medical errors.
Results: Four possible scenarios were defined on how ICT can serve healthcare communication. Two differing conceptual frameworks about communication in healthcare were discussed. Considering "information space" as a part of "communication space" allows the recognition and control of the source of the semantic gaps in conventional standardization and an enhancement of the role of ICT in improving intra-organizational communication. Moreover, cognitive, social, and organizational dimensions of complexity in interpersonal communication can be managed. Three approaches to control the variability in those dimensions and to promote the role of ICT in intra-organizational communication were discussed.
Conclusion: A multi-dimensional approach is required to promote the role of ICT in intra-organizational communication in healthcare. Parallel to conventional standardization, at least three dimensions need to be addressed: controlling the effect of the social context, developing standard information processing skills, and most importantly, controlling variations in care practices' performance.

1. Introduction

Mounting evidence indicates that errors in healthcare intra-organizational communication are accompanied by a rise in medical errors that result in morbidity and mortality [1-3]. Communication failures, particularly those due to an inadequate exchange of information between healthcare providers, remain among the most common factors that contribute to the occurrence of adverse drug events [4]. In a retrospective review of 14,000 in-hospital deaths in Australia [5], communication errors were found to be the leading cause, and were twice as frequent as errors due to inadequate clinical skills [5-7]. In another study, 37 percent of errors in a critical-care unit were found to be the result of problems in the verbal exchange of information between nurses and physicians [8].

Information and Communication Technology (ICT) has considerable potential to improve communication in healthcare [4]. As recently suggested, however, ICT can also increase medical errors due to problems apparently caused by ICT in intra-organizational communication [9-11]. Nevertheless, little has so far been learned about the reasons for these side-effects of information systems. Therefore, it is crucial to determine just how ICT applications might or might not be beneficial. To examine this question more deeply, one needs to understand problems in the current healthcare intra-organizational communication, the potential improving roles for ICT, the current approaches to using ICT in healthcare communication, and the probable pitfalls. Basically, standardization precedes every successful computerization [12]. One of the central issues to be addressed is standardization and its effect on successful communication through ICT channels. Through this focus, we will be able to elucidate how and how not to draw upon ICT to improve intra-organizational communication.

This article is a critical appraisal of the published literature about empirical studies, points of view, and theories from linguistics, cognitive psychology, sociology, medical informatics, quality and organization in healthcare, and Computer Supported Cooperative Work (CSCW). We examine several of the problems inherent in healthcare communication and elaborate upon the source of errors due to communication problems. Next, we evaluate the possible roles that ICT can play in improving healthcare intra-organizational communication. Theoretical frameworks relating to improving communication in healthcare and their impact on standardization approaches and ICT application are then appraised. Finally, we discuss the limitations that hinder effective standardization in healthcare communication and make suggestions regarding other approaches.

2. Background

Communication in highly specialized and collaborative healthcare work is both essential and critical [13]. Tasks in healthcare environments are information-intensive, and to be performed properly a specific task requires a precise set of information, which is obtained mainly through direct interaction[1] with colleagues but also through using Patient Care Information Systems (PCISs) [7, 15, 16]. Interpersonal communication constitutes the greatest part of intra-organizational communication in healthcare [17, 18], and the more that healthcare workers play a role in direct patient care, the more they are involved in communication [15]. Studies, for example, show that among the care providers medical and nursing staff are the main communicators in healthcare organizations [7, 16]. In this paper interpersonal communication is frequently used to represent intra-organizational communication.

In the literature, interpersonal communication is categorized as synchronous vs. asynchronous [18, 21]. Technically, when the message of a communication is broadcast and received simultaneously, it is called *synchronous*[2]. In healthcare, *synchronous* channels have been identified as the main interpersonal communication channels [7, 18-22]; among them, verbal[3] communication is recognized as the most prevalent [18]. Verbal communication is almost always synchronous and potentially interruptive in its nature [7, 19, 20]. Studies have reported that verbal interruptive communication comprises 11-35 percent of all healthcare communication [7, 15]. However, researchers who studied conventional conversation in the workplace reported that communication regarded by one person as intentional was perceived as interruptive by the person being addressed [24]. Whether verbal communication is interruptive

[1] The word *"interaction"* here means communication either between people or between humans and machines [14].
[2] In healthcare, an interaction is considered to be synchronous when two parties interact simultaneously.
[3] When spoken language is used as a symbol system for a message exchange, the interpersonal communication is called verbal communication [23].

appears to be a subjective issue, and the frequency of interruptions reported may therefore be underestimated.

In healthcare, *asynchronous* communication is less prevalent. It is, however, an important part of interpersonal communication, since communicators are able to organize their message or the information that they intend to exchange. Communication through PCISs, such as a patient's medical records, notes written on boards (e.g., white-board notes), e-mail, faxes, and communication through web-based applications, are among the most common forms of asynchronous communication. In daily healthcare work, care providers exchange much registered information in PCIS via synchronous interactions. Communication between a physician and a nurse during a ward round, for example, includes not only an exchange of structured data (e.g., found in patient charts) but also a discussion about unstructured information (e.g., what nurses have to say about a patient's emotions, and so forth).

3. Source of errors in interpersonal communication

In the literature, synchronous channels are considered a primary source of inefficiency and errors in interpersonal communication in healthcare [7, 18-22]. These channels can hamper healthcare practice for at least two reasons. First, for most synchronous communication in healthcare, especially face-to-face interactions, interruption is unavoidable. The introduction of synchronous interruptive channels in such a healthcare environment has a negative impact on the working memory and performance of care providers [21, 22, 25]. Interruption can lead to distraction and forgetfulness, and if it happens frequently it can lead to cognition overload and to errors [7, 25-27]. Therefore, to contribute to a more efficient performance on the part of healthcare professionals, unnecessary synchronous interruptive communication should be reduced.

Second, the information exchanged via synchronous channels either is not registered in PCIS or is registered with a delay, which results in a negative effect on the institutional memory. It is suggested that the biggest information repository in most organizations resides within the heads of staff members, and the most updated information can be found with individuals rather than elsewhere, for example in patient dossiers or information systems [6, 28]. Such claims denote the fact that communicators fail to register the important exchanged information in PCIS appropriately and timely. Cooper et al. [29] observed how a maternity ward staff in an interruption-driven environment failed to enter patient data into an Electronic Medical Record (EMR) at appropriate times. The failure to register patient data in PCIS has a detrimental effect on the work of others who rely on documented data in their work process [4]. Therefore, decreasing synchronous interactions and increasing asynchronous ones can help to improve organizational memory and thereby the quality of healthcare.

Nevertheless, despite the disadvantages of synchronous interactions at the organizational level, they are valuable at the individual and interpersonal level. They facilitate mutual understanding among healthcare professionals, allowing them to make instant corrections that prevent misinterpretation, to give feedback and to update instantly, and to synchronize their work activities [1, 30]. For these reasons, synchronous communication is considered important in avoiding errors and providing qualitative care. Therefore, to improve healthcare interpersonal communication, a trade-off has to be sought between the intention to reduce interruptions and to improve organizational memory (by reducing synchronous interruptive communication) on the one hand, and to support the mutual intelligibility of care providers (by giving room for synchronous interruptive communication) on the other. The optimal trade-off point will be that at which ICT provides the maximum benefit for intra-organizational communication. Later in this article we demonstrate that the trade-off point also reveals the restrictions under which ICT should be expected to play a role in interpersonal communication. To identify the trade-off point, however, we first need to know how information systems can be useful and how this synchronous communication can be substituted by an asynchronous method or be managed properly through information systems.

4. Role of ICT in refining interpersonal communication

We argued that synchronous communication is the most problematic aspect of healthcare interpersonal communication, although it is necessary to promote interoperability. Thus, in order for an information technology to improve healthcare intra-organizational communication, it needs either to shift information-exchange processes from synchronous to asynchronous mode or to prevent care providers' interruptions by providing necessary information and interpretations for their instant needs.

At least four scenarios can be defined in terms of how information technology has been adopted in healthcare communication. Each scenario is built upon the previous one and complements the next one. The role of information system has gradually been promoted in each scenario and each IT systems falls into one of these scenarios based on the role they play in communication process (Figure 1).

In the first scenario, information technology is used to store and to retrieve patient data for different purposes; its role is that of *data repository*. In the second scenario, information technology serves as a *communication medium* through which certain healthcare interactions can be performed asynchronously. This scenario has been widely adopted in healthcare communication; Electronic Data Interchange (EDI), Internet, and e-mail fall into the second scenario as they mainly used for data communication in healthcare. In the third scenario, information technology acts as the *integrator* to help care providers to acquire meta data and to integrate different pieces of patient data asynchronously. For example, a central EMR that is accessible at multiple locations in a hospital can reduce the number of communication processes (e.g., telephone calls) to access separate bits of single patient information produced by various care providers and stored in different databases. In the fourth scenario, information technology can take over the role of *human communicators* and participate in a synchronous interaction with humans. In other words, information technology is able to interpret information and to generate appropriate feedback or reactions. Decision Support Systems (DSS), for example, can act as acknowledged professionals that have access to different sources of information and act upon the received information by providing healthcare professionals with necessary advice and without interruption in their work or that of their colleagues. In that sense, information systems can be considered to play the role of communicators.

In literature, one can distinguish two general conceptual frameworks that represent two different approaches to communication improvement in healthcare. Some researchers view "communication space as a part of healthcare information space", while others consider it to be "larger than the healthcare information space".

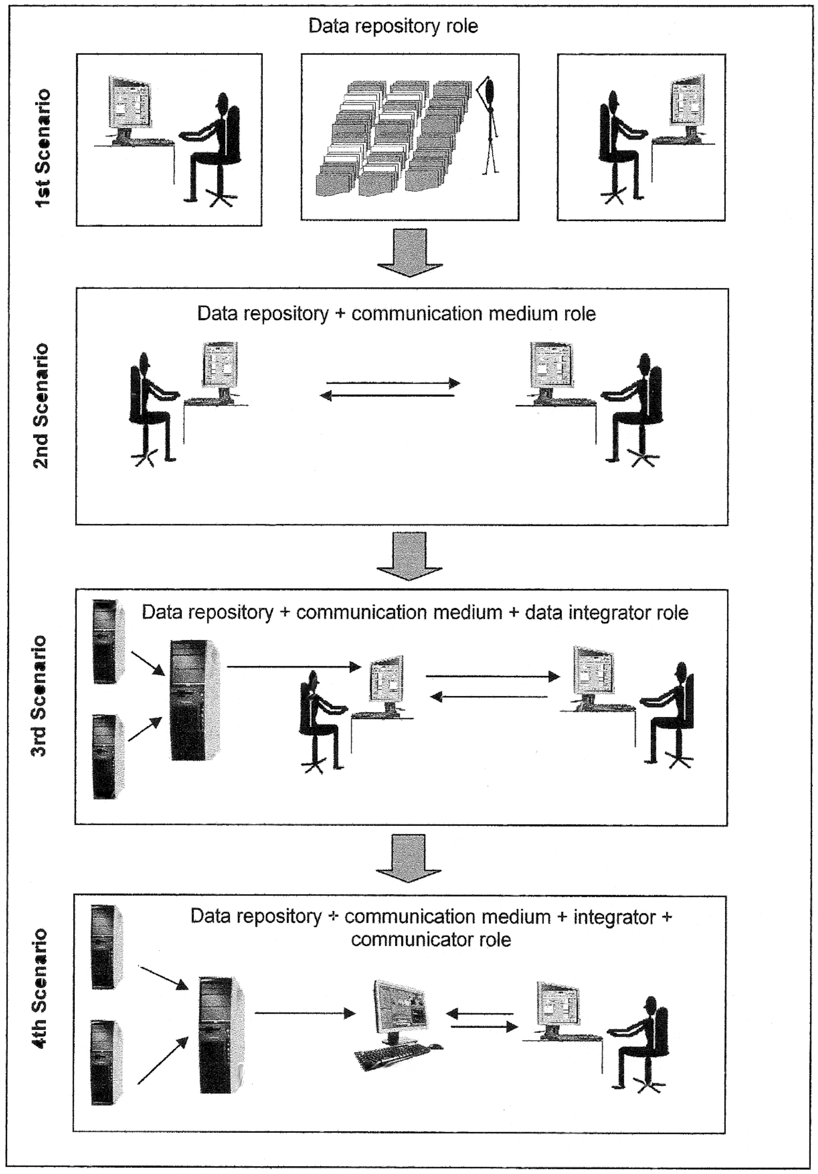

Figure 1. Four scenarios represent how the role of IT has been promoted in healthcare communication.

5. Two different conceptual frameworks

In the first conceptual framework, which is a common notion in Medical Informatics, the "communication space" is considered to be a part of the "information space". Communication is considered as "the process by which information is exchanged between individuals or computers through the use of a commonly accepted set of symbols" [12]. Three dimensions are considered for every communication: communicator(s), communication media, and the exchanged information. In practice, the focus is on the *informative aspect* of communication processes: information and the methods by which it is transacted between computer systems. Successful communication is defined as leading to *interoperability* between the systems. In the course of communication, syntactic interoperability refers to the ability to maintain the syntax of the exchanged information. Whenever the transaction is on the basis of "shared, pre-established and negotiated meaning of terms and expressions", semantic interoperability will also be established [31]. The role of communication space is considered to comprise only part of the total information-exchanging processes [1, 6] (Figure 2), and the environment within which communication takes place does not play a central role [1, 12, 22, 32]. Therefore, in this conceptual framework an improvement in communication is sought through standardization of information registration, transaction, and integration procedures.

In the second conceptual framework, communication space is not considered to be a part of healthcare information space: rather, it is seen to be larger (Figure 2). In this framework, which is a common notion in cognitive and social sciences, communication is not viewed merely as an information-transaction process but is considered one that always centers on coordination and on establishing, testing, and maintaining relationships [9, 33, 34]. In other words, the focus is on the results of communicative exchange. Therefore, in the complex healthcare environment a successful communication amounts not only to *interoperable systems* but also to *interoperable people*. Since information space is a part of communication space, the interoperability is not considered only for information system communication. It also includes gaining "mutual intelligibility" or "shared understanding" between human communicators [14].

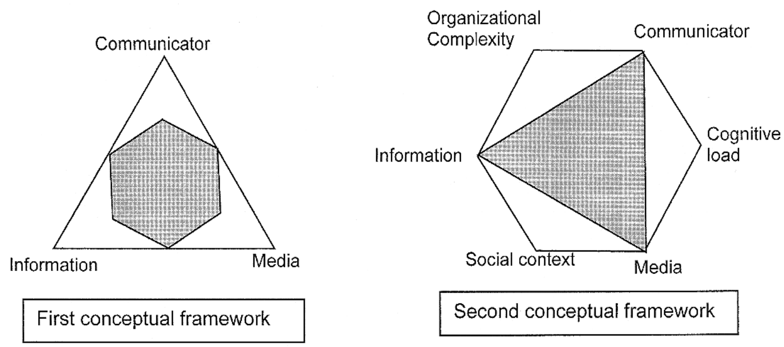

Figure 3. The triangle represents information space and its triple dimensions, while the hexagon represents communication space and its six dimensions. The first conceptual framework considers information, communicator, and media as the triple dimensions required for achieving communication objectives; however, in the second conceptual framework, social, organizational, and cognitive dimensions are also equally important.

The mutual intelligibility of the communicators, on the other hand, is greatly complicated by their communication environment. Besides the communicator, media, and information, three other important dimensions can be recognized for interpersonal communication: cognitive, social, and organizational. The intricacy that exists along these three dimensions gives rise to the complexity of healthcare interpersonal communication. Improvement measures according to the second conceptual framework thus need to generate ways to cope with these complexities. This can only be achieved through jointly organizing the environment within which the information is produced, exchanged, and interpreted.

5.1. COMPLEXITY AT THE COGNITIVE LEVEL

One main reason for the complexity in interpersonal communication is the *cognitive load* that the decoding of communication messages imposes on the communicators. The semantics of a message are largely dependent on factors that influence the encoding-decoding process [35, 36]. Two types of factors, internal and external, are at play here[1], and any variations in them impose a heavy cognitive burden on communicators [23]. The external factors are related to the communication environment and will be evaluated in the following topics. The most important internal factor is related to the "knowledge ground" that is essential for interoperable communication [39].

The perception of a patient's condition and the state of medical treatment in general are determined by several sources of distributed information that together can be seen as one body of knowledge [28]. In order to use this knowledge it is not sufficient to have all of the necessary information from different sources aggregated in one place (e.g., an EMR). To render disparate pieces of information useable for care purposes, they have to be integrated. This integration is a cognitive process of building semantic relationships and links.

On one level of this integration the semantic links are built between items of information, while on another level the links are also to be built between perceived information and the background knowledge of communicators. The first level of integration can be achieved by ICT in an integrator role. However, the second level of integration is the product of the mutual effort between communicators to implement an encoding-decoding process in a manner that results in more or less the same understanding about a subject [14, 35]. Synchronous interactions allow communicators to learn how to encode messages, taking into consideration each other's immediate knowledge and perspectives. Such a mutual learning mechanism in interpersonal communication reduces the cognitive demands for the production and comprehension of communication messages [23]. This level of interaction remains a challenge for ICT application in interpersonal communication, especially for its communicator role. Hayes and Reddy [40] argue that the central difference between interpersonal communication and existing interactive

[1] Based on the mechanical-mathematical model of communication, proposed by Shannon and Weaver [37], a sender encodes a message, for example, by putting an idea into words. This message is then broadcast to a receiver. The person or the device that receives the message decodes the signals to formulate meaningful content. Finally, the receiver may send feedback to the sender to indicate whether the message was understood [38].

computer systems is robustness: the ability to respond to unanticipated circumstances and to detect and remedy troubles in communication.

5.2. COMPLEXITY AT THE SOCIAL LEVEL

Healthcare is a social environment that determines a context for care providers communication: *social context* [41]. The immediate impact of the social context is a "social dimension" for every communication and for every item of exchanged information. This social dimension plays an important part in understanding the core message and in gaining interoperability during interpersonal communication. Moreover, it affects the productivity and effectiveness of communication [42]. Hartly [41], for example, explains the effect of this social dimension in distinguishing the role that a communicator may take in different circumstances: e.g., that of a friend vs. that of a boss.

Communication channels vary in their ability to convey different levels of the social dimension. Face-to-face communication facilitates the richest level, followed by audio/visual, audio-only, and written or Computer Mediated Communication (CMC) [43-45]. If the social dimension of a communication is damaged, for example by standardizing its message or changing its communication channel, the semantics of the message will be hampered accordingly. Therefore, in applying ICT for healthcare communication, maintaining the social dimension of exchanged information is necessary for gaining mutual intelligibility between communicators.

5.3. COMPLEXITY AT THE ORGANIZATIONAL LEVEL

Healthcare systems are dynamic organizations in which not only the actors but also objects and information sources move around [17, 28] and tasks are more or less interrelated and contingent. In such a situation, tasks are carried out by "a collaborating ensemble of actors engaged in a dynamic teamwork characterized by continuous *synchronization* of the many actions and actors involved" [30, 46]. Healthcare systems are inherently constrained by time and resources at the same time that healthcare personnel are required to *coordinate* frequently with each other [6, 46]. The dynamic coordination results in an ongoing process of synchronous negotiations among care providers to align and adjust their work trajectories, to determine how to use shared resources, and to remedy contingencies, urgent problems, and unforeseen conflicts [14, 46].

In healthcare systems, interpersonal communication is the prevailing method of acquiring information, both for task performance and for continuous coordination [7, 21, 46]. Since asynchronous channels fail to meet these needs, healthcare personnel frequently turn from applying asynchronous IT channels to ad hoc synchronous interruptive communication [6, 47]. Reducing the conditions and controlling the factors that necessitate continuous coordination between healthcare personnel can help to reduce the ad hoc synchronous interactions between them. This way, the possible interactions between healthcare personnel can be predicted and be considered in ICT design and applications in order to substitute interpersonal interactions.

6. Standardization approaches

Standardization is fundamental and precedes communication through information systems [12]. The level of the required standardization, however, varies for the different communication scenarios. For data repository and communication medium roles, standardization must entail data registration and communication messaging methods. For these purposes, a wide range of data coding, data transactions, and terminology systems exist in the healthcare domain [48, 49]. However, to some extent for the role of data integrator and mainly for the role of communicator in the information system, standardization has to include the semantics of the exchanged information. Among the conceptual frameworks mentioned, the first tries to establish semantics of the exchanged information through terminology systems, agreed modules of communication, and clinical concepts: ontological models. These models are representative of clinical concepts in terms of the formal and computer-processable specifications of the clinical contents [50]. Once these ontological models are shared between different information systems, semantic interoperability between them becomes possible [33].

The first conceptual framework will inherently have a limited impact on the standardization of communication in healthcare. In practice, the semantic aspect of the communication is minimal. Though this standardization possesses many advantages for information sharing (syntactic interoperability), it carries no assurance that the communicators can reach an agreed level of interpretation of the shared information (semantic interoperability) [33]. As a result, in many instances, where for example the information systems and the standards are the same, the intervention of an intermediary human agent is still necessary to interpret the exchanged messages and to fill the semantic gaps [51].

Moreover, although ontological frameworks can facilitate building semantic interoperability in communication between information systems [50], they have three intrinsic limitations. First, ontological models are designed only for specific domains (e.g., for internal medicine) and organizations (e.g., for solo-practice specialists). This specificity in design, which is necessary for semantic standardization and interoperability, jeopardizes generalization to other domains and to other organizations. Second, the development of ontological models requires a sharp line to be drawn between the developing area of medical practice, which is called “knowledge domain”, and “information structure”. In the constantly evolving science of healthcare, this is often difficult, if not impossible, to achieve [52]. Third, in defining ontological models, only formal communication is considered and informal communication is usually ignored [50]. Although no exact statistics represent the frequency of informal interactions in healthcare organizations, direct and indirect empirical evidence suggests that most synchronous communication consists of informal interactions [18, 32]. Therefore, standardization based on the first conceptual framework will only support to a limited extent the application of ICT as communicator.

In standardization based on the first conceptual framework, there will be *semantic gaps* that the current standards cannot cover [49]. For example, in a research project focusing on the development of a reference architecture for an inter-institutional health information system, Lenz et al. [49] identified concurrent standards in use. The group then categorized and distinguished standards with respect to their ability to cover technical vs. semantic integration on the one hand and data vs. functionality integration on the other. By mapping and putting all the standards into place, a semantic gap was revealed that could not be covered by any of the standards. Thus, to fill the semantic gaps and to address the issue of mutual intelligibility in formal communication, complementary methods of standardization are necessary.

The complementary methods must address ways to control the factor variations that affect healthcare interpersonal communication; to change interactions from informal to formal; and to promote the impact of current standards in healthcare. In the second conceptual framework, it is argued that to maintain semantic interoperability, the standardization domain needs to extend into the communication environment and include, for example, the role, behavior, and language of the communicator. For instance, in order for a user to interact successfully with an information system, he or she has to follow the standard rules and to work in a manner conceptualized by the system’s designer [14]. Moreover, it is possible to design standard methods for information processing and transaction within which semantic relations and links for every potential step are already defined. The compliance of healthcare personnel with such standard procedures is expected to reduce the effect of the variables from cognitive, social, and organizational domains of healthcare communication space and to improve the mutual intelligibility of their formal interactions. Three standardization approaches are discussed in the following sections (Table 1).

6.1. CONTROLLING THE SOCIAL DIMENSION

The missing social dimension of communication has been evaluated substantially in asynchronous CMC. Early studies of CMC proposed that this method filters out cues from the social context of communication [53] and distorts the communication [54]. More recent studies, however, suggested that the CMC communicators can actually communicate successfully, but it takes more time than via face-to-face communication [55]. Therefore, the basic difference between CMC and face-to-face communication is the rate at which communicators can establish interoperability [55]. This difference in speed was also found to be relevant in a recent study of applying CMC to enable committees to meet virtually to agree upon the priorities and commission projects in healthcare [56]. Studies, moreover, suggested that missing contextual factors in CMC is mainly a socio-technical interaction matter than only a technical matter (media bandwidth) [54]. There are many socially determined variables that affect how, why, when, and where such media are used. Controlling the dynamic effects of social context, therefore, can create a situation where media richness is less important to the effectiveness of communication, irrespective of media bandwidth [54].

Moreover, it has been argued that a method of dealing with the social character of communication can be taught to and cultivated among communicators through asynchronous IT channels [57]. Studies, for example, have indicated that CMC users develop the ability to express in written form the missing values of direct communication [45]. Such a notion can be adopted in order to improve semantic interoperability in IT applications in healthcare, especially where an information system is used as a medium (Table 1).

It is also possible to design and to use a system of *standard meta-signs* that are not central to the message of a communication but that reflect communicators' ideas, feelings, and thoughts about the information transacted through IT channels. Such standards can promote social presence and improve interoperability by controlling the effect of social context on interpersonal communication. We could not find anything in the literature that reports on applying these kinds of standard meta-signs in interpersonal communication. However, it is rational to imagine that semantic interoperability could utilize standard meta-signs. For example, a laboratory specialist could use them to indicate the extent of certainty about a test result. This would avoid the need for the person who requested the test to make a phone call to confirm the result. Another example would be the use of a standard meta-sign indicating the reason for issuing an unusual prescription; this could render it unnecessary for a pharmacist to phone and inquire about it. Moreover, an application such as openEHR (open Electronic Health Record) has the potential to support the use of standard meta-signs. With a dual-model approach (i.e. Reference Model and archetypes), openEHR can relate every standard meta-sign with a definition and domain-specific constraint to promote communicator interoperability [50, 58]. By improving semantic interoperability, these standard meta-signs can help to reduce synchronous interactions around asynchronous communication.

6.2. CONTROLLING THE COGNITIVE DIMENSION

Many interoperability problems in communication through IT channels are potentially due to nonstandard information processing routines, like inappropriate coding of data. Such inappropriate routines develop if care providers have not been instructed about the coding purpose or have no clear idea about it. Winthereik [59] observed how Danish, Dutch, and British GPs coded patient diagnoses into their information systems, and realized that they used coding systems differently and according to their local conditions. They were confused about how to code diagnoses in cases where they were not told the purpose of the coding process, whether their coding was for billing or research purposes, or for communication with other colleagues.

The rate of synchronous interactions will be reduced, time will be saved, and collaboration will be improved if healthcare professionals learn how to process (i.e., acquire, record, and communicate) necessary information effectively and efficiently [60, 61]. A recent review article about the information-seeking behavior of doctors suggested the lack of search skills is a common barrier to using information sources [62]. An important way to improve this is to implement training programs that instruct healthcare professionals about where and how to find the information they need (e.g., when working with EMR) and how to record information so that it is understandable for other professionals [62-64]. Studies showed that coding accuracy is improved for residents following a coding and documentation training program [65, 66]. Educational programs, therefore, have to aim at improving care providers' understanding of coding purposes and at applying appropriate methods in working with ICT (Table 1).

6.3. CONTROLLING THE ORGANIZATIONAL DIMENSION

Procedural standards, such as guidelines, are able to construct new links between work practices and to transform their functions, capacities, and properties within a care process. They standardize, *align,* and *integrate* a set of practices, actors, and situations. By determining what to do when, and in what sequence (for example, how to evaluate patients, to perform diagnostic and therapeutic procedures, and to report patient data and findings), these standards can control variations in performing healthcare practices. By coordinating the various tasks within and between different work practices, these standards can greatly reduce unexpected variation that is amenable to more synchronization and coordination [67] (Table 1).

At healthcare organization level, standardized care pathways built upon the trajectories of most patients describe *interdisciplinary* steps that care providers need to take for certain types of patients. It has been argued that in a standardized care path 70-80 percent of the steps and decisions can be delineated beforehand, thereby avoiding the need to configure the care trajectory repeatedly for each patient [63, 68]. This would potentially mean avoiding many unnecessary and routine activities that result in a great deal of ad hoc interruptive synchronous communication and coordination. Moreover, in most cases, considerable communication among healthcare personnel in a standardized care path can be predicted and replaced by IT channels [69].

Table 1. Standardization approaches to control variation at the cognitive, social and organizational dimensions of healthcare communication.

Standardization approach	**Objective**	**Example**
Controlling the social dimension	To promote social presence in asynchronous communication through IT channels.	A standard meta-sign that explains the reason of an unusual prescription for a pharmacist.
Controlling the cognitive dimension	To promote developing standard information processing skill by healthcare staff.	How to record information so that it is understandable for other care providers.
Controlling the organizational dimension	To promote aligning and integrating a set of practices, actors, and situations.	Guidelines and standard care paths.

Standardizing highly collaborative care processes has to include implementing feedback mechanisms. By informing and updating fellow care providers in the same process, these feedback mechanisms can prevent many of the synchronous interactions concerning coordination. Feedback mechanisms, moreover, can reduce the cognitive overload in asynchronous interactions. Dahl [70] studied location-based virtual notes that allowed hospital workers to leave short digital messages linked to relevant physical locations (e.g., by a patient's bed), so that intended colleagues could pick them up later when entering those locations. One of the main user concerns in this study was the lack of feedback about the posted virtual notes that made users uncertain about whether someone had received the note or had acted upon it.

After care processes are standardized, one can speak of defining role-based communication within and between task structures. The knowledge and information needed to fulfill the intended roles in standard care processes are predictable, and an information system in which this basic knowledge has been modeled can promote interoperability in ICT application based on the fourth scenario [39]. ICT would be able to provide healthcare personnel with the necessary information related to specific tasks, in a specific time and place, and in a specific sequence. By integrating other sources of patient information, for example from laboratory systems, ICT can be expected to work as a communicator in the loop of acquiring, integrating, and interpreting patient data to offer appropriate advice for care providers.

7. Discussion

We have argued that the optimal value of ICT application for healthcare intra-organizational communication will be at the point where changing synchronous interactions to asynchronous ones does not hinder care providers' interoperability. Four scenarios were presented whereby ICT improves healthcare communication; each is built upon the previous one and complements the next one and each one requires a different level of standardization. Two conceptual frameworks were discussed and their impacts on the standardization of communication events in healthcare were elaborated upon. The first conceptual framework has been applied as the basic platform for a standardization process in several systems and in a number of IT applications for information repository, media, and integrator roles. We argued that these standards could mainly cover the syntactic component of healthcare communication and leave gaps in the semantic aspect [49]. To reduce these gaps, standards are also needed to maintain the semantics of the exchanged information. To develop such standards, the standardization process needs to go beyond the syntax of communication messages and to include those aspects of communication that influence the interpretation and understanding of the communication message: namely, cognitive, social, and organizational. This level of standardization enables ICT to assume a communicator role. The second conceptual framework can be a platform for this level of standardization and to support ICT application in the communicator role.

The contribution and maintenance of information in healthcare are collaborative activities performed by various members in the organization. An EMR, for example, is not a simple aggregate of every individual's contribution. Instead, every contribution has to be written, collected, completed, assessed, and accepted or rejected, as well as frequently updated [71]. Rigorous standardization then may necessitate more synchronous interactions to resolve the ambiguities and complexities that appear in exchanged information via asynchronous channels [67]. Therefore, the collaborative nature of information processing in healthcare poses restriction to standardization based on the first conceptual framework; this restriction has to be considered in applying information systems to substitute healthcare personnel communication based on the first conceptual framework [71, 72]. Wherever this restriction was not considered, problems arose due to difficulties in semantic interoperability. For example, empirical studies demonstrated that the volume of synchronous communication rose, relationships among healthcare staff were disrupted, cooperative work was undermined, and medical errors increased [11, 72]. Hence, the successful standardization of interpersonal communication needs another mechanism to help the current standards to meet the requirement for ICT in communicator role.

If the semantics of information processes could be standardized, improvements in mutual intelligibility through asynchronous interactions would be expected. We have argued that many factors affect the semantics of communication processes. In practice, it is not possible to control all of them. Nevertheless, at least ways exist to reduce ambiguities and to improve mutual intelligibility through asynchronous interactions. This means that standardization is necessary for both the information contribution of care providers and for those aspects of the communication environment that produce complexity at the organizational, cognitive, and social dimensions.

In this study, we critically analyzed literature from different scientific disciplines related to improving healthcare interpersonal communication. Whereas much ICT work has focused on the standardization of communication in healthcare, empirical studies show that standardization may actually hamper effective communication [67]. Rather than argue against standardization as such, or against standardization for only limited communication processes, we discussed the form that it has taken within healthcare ICT, and we suggested alternatives. Based on the information from different scientific disciplines, we suggested that promoting the role of ICT in healthcare interpersonal communication requires a multi-dimensional approach. Such an approach – as well as explicit standard systems for data storage data transaction, terminology, and ontology – must address at least three dimensions: social context, the information processing skills of healthcare personnel, and most importantly, standardizing care process. In fact, any IT implementation effort that substitutes interpersonal communication in healthcare must – one way or another – deal with the social, cognitive, and organizational dimensions of communication space.

Communication problems contribute to many IT implementation failures and to patient safety concerns in healthcare. However, to our knowledge, few studies thus far have evaluated the effect of IT systems on cognitive, social, and organizational dimensions of healthcare interpersonal interactions. Even fewer studies have evaluated the effect of combining IT implementation with the improvement measures we proposed in this study. We analyzed literature from diverse scientific disciplines in order to bring new insights into IT applications to improve interpersonal communication, and realized that many research topics concerning the role of ICT in improving healthcare communication are still open. The suggested improvement measures in this paper, for example, represent ideas that need to be confirmed by further empirical studies. The scope in this review might have missed certain relevant issues or failed in some cases to present a deeper analysis. However, we believe that it has raised a number of important foci for future in-depth studies.

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CHAPTER 2

Evaluation of the impact of a computerized physician order entry system on nurse-physician communication: a mixed method study

Habibollah Pirnejad, Zahra Niazkhani, Heleen van der Sijs, Marc Berg, Roland Bal

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A b s t r a c t

Objectives: To assess the impact of a CPOE system on medication phases by focusing on the effect of the system on medication-related communication of nurses and physicians.

Methods: In six internal medicine wards of an academic medical center, two questionnaires were used to evaluate nurses' attitudes toward the impact of a paper-based medication system and then a CPOE system on communication and workflow. They were used to evaluate how changing from a paper-based to a CPOE system impacts nurse-physician communication during their medication related activities (medication work). Nine nurses and six physicians in the same wards were also interviewed after the implementation to determine how their communication and their work have been impacted by the system.

Results: The total response rates were 54.3% and 52.1% for pre- and post-implementation questionnaires. T-tests were used to analyze the results of the questionnaires. It was shown that after implementation the legibility and completeness of prescriptions were significantly improved ($P<0.001$) and the administration system had a more intelligible layout ($P<0.001$), with a more reliable overview ($P<0.001$) and clearer records ($P=0.027$). The interviews supported quantitative findings. Complementing and combining the results of the surveys with qualitative findings showed communication problems that caused difficulties in linking medication work of nurses into physicians'. To compensate for these, nurses and physicians devised informal interactions and practices (workarounds), which often represented risks for medication errors.

Conclusion: The system introduced many communication problems and workflow impediments to medication phase. Workarounds due to these impediments can contribute to the error induction effect of a CPOE system. In order to prevent such an effect, CPOE systems have to support the level of communication which is necessary to integrate the work of nurses and physicians.

1. Introduction

Medication errors are both harmful to patients and costly for healthcare systems [1, 2]. In hospitals, these errors are common during every step of the medication process – prescribing, procuring, transcribing, dispensing, administering, and monitoring – but they occur most frequently during the prescribing and administering stages [1]. Information systems play an increasingly important role in patient safety [3], and among them, Computerized Physician Order Entry (CPOE) systems have gained extraordinary attention in reducing medication errors and increasing the efficiency of the medication process. For instance, in a recent IOM report, "Preventing Medication Errors", it is recommended that all pharmacists and prescribers use e-prescriptions by 2010 [1].

However, there have been concerns about the extent to which these systems can prevent errors and the conditions under which they can improve the medication process. Recent studies have reported several adverse CPOE system effects on patient safety [4-8], which were explained as having "less to do with the software problems" [9] and more to do with their "problematic implementations" [10]. Nevertheless, studies have suggested ways whereby CPOE systems actually contribute to compounding medication errors [4-6, 11, 12]. Beuscart-Zephir et al. [13] and Kopel et al. [4], for example, demonstrated how these systems can present problems and cause errors in nurse-physician collaboration in their medication related activities, medication work. Moreover, reports on the conditions under which medication errors have been facilitated by CPOE systems have been increasing in the literature [14-17]. Thus, there seems to remain much to learn about when and how such information systems, which are designed to reduce medication errors, may in fact be counter-productive [9].

We evaluated the impact of a CPOE system on nurse-physician communication and collaboration throughout the medication process, and, by focusing on the whole procedure as an interrelated work, we sought to answer the following questions: 1) How did interoperability change in nurse-physician communication after the CPOE system was implemented? 2) How may this change affect patient safety?

Both quantitative and qualitative approaches were used to answer the research questions. The quantitative section was presenting a part of two pre- and post-implementation survey studies that evaluated the impact of a CPOE system on nurses' communication and medication workflow. The data from surveys was then triangulated, i.e. supplemented and combined, by a series of in-depth semi-structured interviews with nurses and physicians.

2. Theoretical background

The role of CPOE systems in reducing errors at the prescription phase of the medication process has been evaluated very well in the literature [14-18]. The medication process, however, is a *loop* of interrelated phases, where each phase determines how the next will be carried out [14]. In this multi-step *dynamic* process, any intervention in one phase (e.g., prescription) will inevitably affect the others as well [18]. Nevertheless, many of the evaluation studies failed to take the dynamic and interrelated feature of the medication process into account [6, 19], and the scope of their evaluations has rarely been extended to include the impact of the system on the entire medication process cycle.

The interrelated nature of medication process requires highly collaborative work of nurses and physicians that has to be coordinated and integrate in a dynamic manner. While such collaborative efforts are paramount to accomplish medication work and to avoid errors [6, 20], they inevitably raise differences with regard to perspectives on the structure and organization of the work [21] and jeopardizes the evaluation the effect of the system. Therefore, it is advocated to focus on the communicative processes of healthcare professionals instead of on notions of tasks or goals as basic units of analysis [21].

Proper communication is required for the necessary coordination and integration in dynamic processes such as medication work [22, 23], and constructing an effective system of communication, as Strauss [24] argues, is in fact a generalized work articulation strategy. However, successful communication is not simply a matter of an information-transaction but involves the usability of the transacted information; it is a process that helps to establish, test, and maintain relationships, meaning, and coordination [6, 25, 26]. The usability of the communicated information, therefore, requires physicians and nurses to attain a common understanding of the data [27]. In fact, work consistency in the medication process depends both on an appropriate and timely information transaction and on a proper understanding of it [28].

Interoperability is defined as "the ability of parties**,** *either human or machine*, to exchange data or information" [25]. An extended application of "interoperability" can be used to imply nurse-physician *mutual intelligibility* in their medication-related communication, either directly or through using a paper-based or an electronic medication system [29]. In accordance with the discussion by Bannon et al. [27] about *Common Information Space*, nurse-physician interoperability can provide a framework for our understanding of the properties of medication-related information that crosses the professional boundaries of nurses and physicians [29]. Such an understanding can be used to highlight the effort that is needed to transfer information from one community into a shared arena [21].

3. Study context

Erasmus Medical Center is a 1237-bed tertiary medical institute in Rotterdam, The Netherlands. A CPOE system, *Medicatie/EVS*®, was implemented in 34 wards from September 2003 until March 2005. The system allows physicians to prescribe drugs electronically and has the capability to recognize and to issue alerts on drug overdoses, interactions, and double medications, based on the pharmacy drug database and the national drug database (the Z-index of the Royal Dutch Association of Pharmacists) [30]. The system was made accessible in physicians' offices in the hospital as well as through every computer connected to the Hospital Information System (HIS). It was also integrated into two widely used information systems – the Hospital Information System (named ZIS) and a basic Electronic Patient Record (Patient98) for reporting and storing lab and radiology test results – and made it possible to navigate from one system to the other as well as to browse patients' records.

In internal medicine wards where we carried out our study, the prescription process begins when physicians finish visiting their patients and are in their offices or at CPOE-connected workstations and enter prescriptions into the system. Medication order entry is only possible for physicians, who are required to have a specific user name and password. In principle, no medication can be given by nurses unless there is a corresponding physician logged in. As soon as the prescribing physician clicks on a print button and/or logs out, a 3.5×10 cm self-adhesive prescription label for each medication is printed out on a special printer (Figure 1). The rest of the medication process – including procurement of drugs, distribution, administration, and monitoring – is handled by nurses[1], who use a paper-based medication management system, called the Kardex-card, for registration and coordination purposes. They can look at patients' current medication data in the CPOE system through HIS and can make lists, but they cannot make any changes to the data. Due to the problems that direct communication of medication orders from physicians to pharmacy department caused, this feasibility of the CPOE system has been turn off. Currently, commonly used drugs are kept in the ward's medication stock supply, and prescribed items that are not included in the stock are ordered by HIS from the pharmacy department by nurses. Nurses are not allowed either to administer drugs from the ward stock or to order non-stock medications unless they have their prescription labels at hand.

The prescription labels contain a variety of information including the name of the patient and the physician, the ward code, and medication, including its administration route, dosage, intervals, and the start and stop date; entering the

[1] In The Netherlands, as in many other European countries, pharmacists do not play an active role in controlling the medication process.

stop date is not mandatory, however, except for critical items such as antibiotics. At the bottom of a prescription label is a small space where physicians can enter necessary notes and remarks that nurses need to bear in mind while administering the medication. Every nurse picks up her own patients' prescription labels from the printer and sticks them on a Kardex-card. On the front of each label on the Kardex-card are empty spaces where nurses are to sign whenever the medication is given to patients or to record remarks when necessary (Figure 1).

Another important output of the CPOE system is called the AMO[1] list, which contains an overview of current medications for each patient (Figure 2). This overview is printable through ZIS and contains the changes in patient medication data. Every midnight (around 12 a.m.), nurses print out AMO lists and use them to check against each patient's Kardex-card and medication cabinet.

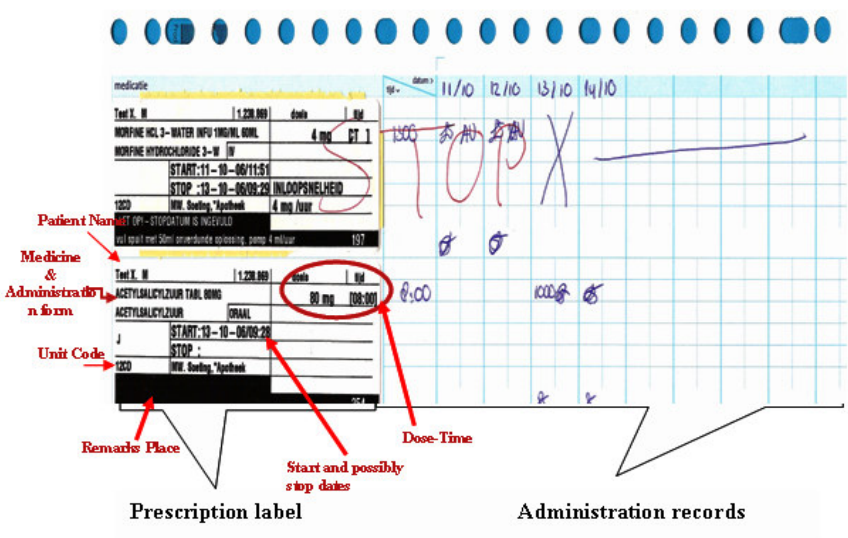
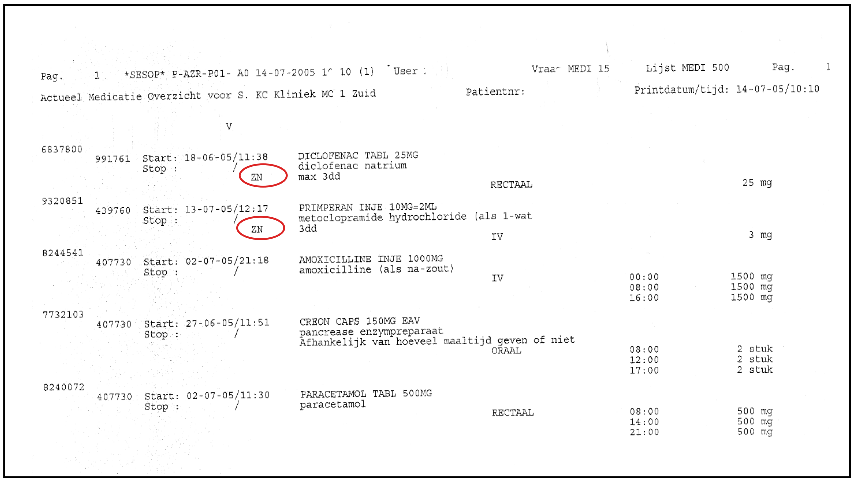


Figure 1. A Kardex-card consists of prescription labels on the left-hand side and spaces to record administration information on the front of each prescription label.

[1] AMO stands for Actueel Medicatie Overzicht (Current Medication Overview).



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Pag.   1   *SESOP* P-AZR-P01- A0 14-07-2005 1^ 10 (1)   User :          Vraa^ MEDI 15    Lijst MEDI 500    Pag.    1
Actueel Medicatie Overzicht voor S. KC Kliniek MC 1 Zuid           Patientnr:            Printdatum/tijd: 14-07-05/10:10

                            V

6837800
     991761  Start: 18-06-05/11:38   DICLOFENAC TABL 25MG
             Stop  :            /    diclofenac natrium
                              ZN     max 3dd
                                                         RECTAAL                        25 mg
9320851
     439760  Start: 13-07-05/12:17   PRIMPERAN INJE 10MG=2ML
             Stop  :            /    metoclopramide hydrochloride (als 1-wat
                              ZN     3dd
                                                         IV                              3 mg
8244541
     407730  Start: 02-07-05/21:18   AMOXICILLINE INJE 1000MG
             Stop  :            /    amoxicilline (als na-zout)
                                                         IV            00:00          1500 mg
                                                                       08:00          1500 mg
                                                                       16:00          1500 mg
7732103
     407730  Start: 27-06-05/11:51   CREON CAPS 150MG EAV
             Stop  :            /    pancrease enzympreparaat
                                     Afhankelijk van hoeveel maaltijd geven of niet
                                                         ORAAL         08:00          2 stuk
                                                                       12:00          2 stuk
                                                                       17:00          2 stuk
8240072
     407730  Start: 02-07-05/11:30   PARACETAMOL TABL 500MG
             Stop  :            /    paracetamol
                                                         RECTAAL       08:00           500 mg
                                                                       14:00           500 mg
                                                                       21:00           500 mg
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Figure 2. Actual Medication Overview (AMO) list. ZN is equivalent to PRN.

Before the CPOE system was implemented, a paper-based medication system (TIMED) had been used in the internal medicine wards. In the TIMED system, physicians wrote their prescriptions on pre-printed slips, and then on an administrative registration form nurses translated the prescription into exact time and dose according to ward routine. A new administration form was produced every day and was placed next to the transcribed order form on the patient's chart.

4. Methods

Both qualitative and quantitative methods were applied to evaluate the effect of the CPOE system on nurse-physician interoperability. To achieve this interoperability, nurses and physicians exchange information either directly, verbal conversation, or indirectly, through recording on any kind of patient care information system [29]. Therefore, any problem in either form of the information exchange can cause problem in nurse-physician interoperability and as a result in their medication activities. Vice versa, it is possible to trace the problems in medication work of nurses and physicians back to the probable problems on their interoperability.

All six internal medicine wards, with a total of 174 beds, were included in our study on the grounds that the medication-related work of nurses and physicians in these wards is considerable. Since nurses play a significant part in almost all phases of the medication process and have a pivotal role in articulating different healthcare providers' tasks, our research was more nurse-oriented. A questionnaire was used to record nurses' attitudes toward the effects of the former paper-based system on their medication work and communication prior to implementation of the CPOE system in internal medicine wards in November and December 2003. In the same manner, in April 2004 a second, slightly different questionnaire evaluated nurses' attitudes towards the system five months after its implementation. The questionnaires were in paper form, were optionally anonymous, and were in the Dutch language, and contained 28 and 40 questions designed to evaluate the paper-based and CPOE systems, respectively. The questions were either multiple-choice or were based on the five-point Likert scale, and they covered topics ranging from system usability to the effect of the systems on nurses' medication work. In developing the main questionnaires, published surveys such as that of Murff et al. [31] about CPOE systems were considered, and the relevancy and understandability of the questions were tested with two nurses.

All 140 nurses active in the internal medicine wards were included in our surveys. The head nurse in each ward was assigned to distribute the questionnaires, to motivate the nurses to fill them in, and then to collect and return the completed forms. We followed up on the returning of the completed questionnaires one, three, and five months after their distribution. Seventy six and 75 questionnaires were returned, for before and after the implementation, respectively.

In 2006, the data was extracted from the questionnaires and analyzed. We carefully selected those questions that were related to the usability of medication data – in prescriptions, AMO lists, and Kardex-cards – and to the reliability of the system's function. Eight questions were common in both pre- and post-implementation questionnaires, while four were specific for post-implementation; all of the chosen questions were based on the five-point Likert scale (Tables 2 and 3). The remaining questions will be reported upon in subsequent papers. Cronbach's Alpha was computed for the chosen set of questions to ascertain their internal consistency, and t-tests were used to analyze extracted data. This part of the study evaluated how nurses, as healthcare professionals, worked with medication prescription data and perceived the quality and usability of the information before and after implementation of the CPOE system. The selected questions were mainly about how physically well medication data is presented by the paper-based and the CPOE systems. Therefore, they were used to inform how the paper-based and the CPOE systems impact *syntactic* interoperability.

In 2006 and 2007, assuming that the system had been adopted and fully integrated into the medication work, we performed a qualitative study. The first and the second authors conducted fifteen interviews with nurses (n = 9) and physicians (n = 6) from internal medicine wards who had working experience with both systems. The interviews were conducted at interviewees working environment where they could show to the interviewers if they find something difficult to explain and provide them with examples for clarification. The interviews were in-depth, semi-structured, one-to-one, and face-to-face, and each one lasted 45-60 minutes. The questions were focused on interviewees' medication work and the impact of the CPOE system on each phase of the medication process. Moreover, the effect of the system on the communication of medication data, on building nurse-physician interoperability, and on collaboration between nurses and physicians in routine medication work was discussed in detail. In the event that a problem in the medication process was perceived, the interviewees' compensating actions were discussed in depth. Whenever it was appropriate, interviewees were requested to compare the CPOE and TIMED systems on the basis of their experience. This part of the research triangulated our methodology because many of our topics for the interviews were those of the questionnaires; the data was also triangulated in the sense that we asked nearly the same questions of both nurses and physicians.

The interviews were voice-recorded, transcribed, and prepared for analysis. Each transcript then reviewed for obtaining general impression, evaluating its credibility, and understanding the use of its information. The data were coded based on Bowling [32] by the two interviewers independently in order to differentiate general themes, i.e. the problems in medication work of nurses and physicians. The analysis proceeded with recognizing: whether the considered problems were because of a problem in nurse-physician interoperability; if yes, whether the interoperability problem was introduced by the CPOE system; and what are the actions on the part of nurses and physicians developed in response to those problems. The inter-rater agreement between the two coders over the above-mentioned issues was assessed by calculating Cohen's Kappa. The non-agreed items then discussed between the authors and compromised upon.

5. Results

5.1. QUESTIONNAIRES

A total of 76 questionnaires (response rate 54.3%) on pre-implementation and 73 (response rate 52.14%) on post-implementation were used for the analysis. Table 1 represents the demographics of the respondents in both surveys; the majority of the respondents were female, practicing nurses, and between 24-33 years old.

Table 1. Demographics of respondents.

		Pre-implementation (N=76)		Post-implementation (N=73)	
		Frequency	**Percentage**	**Frequency**	**Percentage**
Gender	Male	14	18.4	12	16.4
	Female	61	80.3	60	82.2
	Missing data	1	1.3	1	1.4
Age	<=23 years old	11	14.5	13	17.8
	24-33	24	31.6	25	34.2
	34-43	17	22.4	15	20.5
	44-53	20	26.3	18	24.7
	>=54 years old	2	2.6	1	1.4
	Missing data	2	2.6	1	1.4
Professional position	Practicing nurse	62	82.7	55	75.3
	Nurse manager	3	3.9	6	8.2
	Nurse student	8	10.5	10	13.7
	Other	2	2.6	1	1.4
	Missing data	1	1.3	1	1.4

Since a complete respondent match in pre- and post-implementation surveys was not possible, two independent sample t-tests were used to analyze the questions that were common to both questionnaires: numbers 1 to 8. The mean, standard deviation, t-value, and significance of the t-tests are presented in Table 2. The analysis showed that nurses judged CPOE system prescriptions to be significantly better than those from the paper-based system with regard to legibility ($P<0.001$) and completeness ($P<0.001$). However, there was no statistically significant difference between prescription layout in the two systems ($P>0.05$).

The efficiency of data arrangement on Kardex-cards was not substantially changed in comparison to the paper-based administration registration system (P> 0.05); however, the overall layout of the Kardex-card was considered significantly clearer (P <0.001) and the overview on medication data was thought to be significantly more reliable (P <0.001) in comparison to TIMED system. Although administration records on Kardex-cards were considered significantly clearer (P =0.027), their reliability was not thought to differ significantly (P> 0.05) in comparison to the paper-based administration system.

Questions 9 to 12 were specific for the post-implementation questionnaire, and one sample t-test was used to analyze them by comparing them to 3 (the middle value of the five-point Likert scale). The result of the analysis is presented in Table 3. The AMO list was rated significantly clearer (P<0.001) and more reliable (P<0.001) by nurses, who also considered that HIS and the network support working with the CPOE system were reliable (P<0.001). The function of the system's printer was evaluated as a further check on the process. This function was rated reliable significantly (P<0.001).

Although the presented results provided a good insight into the improvements in medication data communication, especially with respect to its syntactic aspect, they did not provide sufficient insight into how the system impacted nurse-physician interoperability. To determine how interoperability was changed and to triangulate the quantitative findings, we conducted interviews with nurses and physicians. The following sections present the results of the qualitative study.

Table 2. Questions 1 to 8 were common in pre- and post-implementation surveys. The table represents the translated questions based on the five-point Likert scale and their statistical analysis using the t-test.

Questions	Scales	Mean	Std. Error Mean	t	Sig. (2-tailed)
1.The layout of prescriptions is:	Confusing 12 3 4 5 Clear	3.67 3.63	.113 .118	.282	.778
2. The legibility of prescriptions is:	Bad 12 3 4 5 Good	2.75 4.01	.108 .116	-7.981	.000
3. The completeness of prescriptions is:	Bad 12 3 4 5 Good	3.37 4.03	.102 .105	-4.495	.000
4. The arrangement of data in the administration registration system is:	Cumbersome 12345 Efficient/practical	3.68 3.85	.103 .099	-1.202	.231
5. The layout of the administration registration system is:	Confusing 12 3 4 5 Clear	3.35 3.86	.097 .092	-3.831	.000
6. The overview of medication data in the administration registration system is:	Unreliable 12 3 4 5 Reliable	3.11 3.79	.097 .091	-5.104	.000
7. Administration records in the administration registration system are:	Confusing 12 3 4 5 Clear	3.09 3.42	.110 .105	-2.231	.027
8. Administration records in the administration registration system are:	Unreliable 12 3 4 5 Reliable	3.09 3.23	.103 .127	-.903	.368

- AMO stands for Actueel Medicatie Overzicht (Current Medication Overview).
- In the “Mean” and “Std. Error mean” columns the upper values belong to the pre-implementation and the lower values belong to the post-implementation survey.

Table 3. Questions 9 to 12 were specific for the CPOE system. One sample t-test was used to compare the mean of each question with the hypothesized value of 3.

		One sample t-test (test value = 3)			
Questions	**Scales**	**Mean**	**Std. Deviation**	**t**	**Sig. (2-tailed)**
9. Information in AMO is:	Confusing 12 3 4 5 Clear	3.60	1.139	4.520	.000
10. Information in AMO is:	Unreliable 12 3 4 5 Reliable	3.75	.852	7.472	.000
11. HIS and network support for working with the CPOE system is:	Unreliable 12 3 4 5 Reliable	3.64	.747	7.091	.000
12. The performance of the prescription labels' printer is:	Unreliable 12 3 4 5 Reliable	3.71	.819	7.227	.000

5.2. INTERVIEWS

The chance-corrected agreement between the two independent coders was good (K=0.69; 95% confidence interval [CI], 0.84-0.56). The interviews, in general, revealed that both nurses and physicians considered the system to be an improvement in their medication work compared to the old paper-based system. They however complained about problems in coordination and collaboration. These problems forced them to develop informal[1] rules and work methods (i.e. workarounds) and to adapt the system in a way that it met their work requirements. As this later part of our finding was not reflected by the quantitative research, we report on it explicitly in the following sections.

5.2.1. Physicians' perspective

Physicians especially appreciated the system with respect to its decision support during prescribing or adjusting medications, to the possibility to prescribe from different locations in the hospital, and to the good documentation of patients' prescription data. In practice, however, prescription labels and AMO lists

[1] Informal is used here to represent the rules and manners in working with a system that were not formally considered and outlined in the system design.

generate several communication problems that hinder interoperability (Table 4). First, AMO lists are produced only once every 24 hours and during night shifts, and depending on the routines of different wards, the older AMO lists are either archived in nursing records or discarded. They do not convey the most recent changes in patients' medications if these occurred after midnight. They also provide no information about changes older than 24 hours: it is not clear, for example, what medications a patient used two days previously. Second, AMO lists are a CPOE system product and contain no medication administration record. The Kardex-card in working with CPOE is the only administration reference, but it is not available for physicians at a patient's bedside or when they are prescribing medications. By using AMO list as the source of patient medication data during medical rounds, physicians in effect have no proper overview and frequently have to rely on their own memory, on nurses' reports, or on a patient's verbal information. Therefore, the system prevents physicians from actively participating in monitoring medication.

> "What the system does [support] and what is good about the system is especially that it has a good signaling function for interactions or for the moment when one adjusts several drugs. What it does not [support is that] there is no way to use the system to prevent giving wrong medications to the wrong patients. There is no coupling between my prescription and a patient administration registration reference." [A senior physician]

If they are to fulfill their communicative function, prescription labels have to be picked up and processed by nurses, otherwise the prescription data is not formally transferred to them in the medication process loop. However, there is no way for nurses to be informed by the system that new prescription labels are printed out and waiting for them. As a result, physicians have to inform nurses, directly or through phone calls, every time they issue a new prescription label; this is not always possible for them. Physicians, moreover, have to inform nurses directly in the event that they prescribed medication that was not in accordance with ward routine, or when they requested special attention be paid to the administration of a particular drug at the bottom of the prescription label. Without direct communication, there is a high risk that those instructions will not be seen by the nurses.

There are several reasons why orders are not usually entered into the system timely. First, entering medication orders into the CPOE system is time-consuming especially when new patients are admitted and medications are prescribed for the first time. Second, writing medication orders interferes with the other duties of physicians working under high pressure contingency, for example, with their academic and training responsibilities or need to discuss their patients with senior colleagues. Third, physicians sometimes have to wait for more information or evidence before they can decide upon an appropriate medication therapy. Nevertheless, these delays cannot be easily coordinated with nurses' duties and so result in problems in their medication work.

Table 4. Workflow problems due to interoperability problems introduced by the CPOE system into physicians' medication workflow; the system-related source of the problems; and physicians' compensatory actions.

Workflow problems due to problems in interoperability	Source of interoperability problems	Compensatory actions
• Physicians cannot be sure whether nurses have picked up and filled a prescription order that was sent through the system.	• The system cannot inform nurses that a new prescription label has been printed out.	• Physicians inform nurses directly or through phone calls that new prescription labels have been issued.
• In working with the system, there is no way for physicians to monitor and prevent giving wrong medication to the wrong patient or to adjust their prescriptions according to the patient's medication administration history.	• There is no link between a patient's current medications data and administration records.	• As regards special timing, route, and particular attention to the administration of a drug, physicians have to inform the nurses directly, as well as enter a note at the bottom of prescription labels.
• Changes older than 24 hours and the most recent changes in patients' medications are not accessible through AMO lists for physicians at the bedside (missing data).	• AMO lists are produced to check and control the mechanism of nursing medication work. For physicians these AMO lists are not sufficiently updated.	• Physicians have to leave the drug monitoring task to nurses, rely on their bedside reports in their decision making, or ask patients.
• Nurses fail to pay special attention to the details on physicians' medication orders.	• Information on prescription labels is printed in small letters in black and white.	• Physicians have to work with an abstract form of information and make brief notes.
• Patients' clinical data (e.g., pulse, weight, temperature, etc.) is not easily accessible for physicians at the time of prescribing.		

5.2.2. Nurses' perspective

Nurses believed that the CPOE system prescriptions were more legible, complete and reliable, and they did not experience the problems they had had with the paper-based system. They also believed that the Kardex-card provided them with much clearer as well as more readable and reliable administration data; many nurse-physician interactions involving problems with those issues disappeared with the implementation of the CPOE system. Nurses, however, consider that physicians do not usually enter their orders into the system in a timely manner, and so prescription labels may be delayed by up to few hours. This can be quite disruptive to nurses' work, especially as in principle, and following implementation of the CPOE system, they are not permitted to accept verbal instructions given by physicians. Moreover, nurses cannot order non-stock medications in case they do not have their prescription labels at hand. In practice, for medication work to run smoothly, nurses have developed informal strategies to deal with the communication of orders. For one thing, they still accept verbal instructions, though this approach is informal and highly dependent on the professional relationship and trust in the physician (Table 5). Moreover, a special paper-based form at nursing stations, called *appointment form*, is used for physicians to write down and sign their medication orders if time is an issue or it is impossible to enter prescriptions directly into the system. However, these orders must be entered later by the physicians.

The physicians' delay in prescribing medications causes nurses to receive prescription labels late, which in turn holds up their medication work, an issue that has become a part of routine. Hence, nurses are used to phoning the physicians frequently, requesting that they enter their orders into the system and issue the labels. For many of the routine medication orders, nurses may not wait to receive the labels, but will work on the basis of notes that they take during medical rounds. Nevertheless, they continue to call the physicians because they still need prescription labels to authorize their work. Nurses also frequently find that physicians change or forget details of their verbal orders when they prepare to enter them into the system, and as a result they issue prescription labels that do not tally with their verbal instructions.

The medication order entry for newly admitted patients is normally delayed because the first entry into the system can be time consuming, especially if physicians have to enter several of their patients' home-used medications as well. For patients admitted from the emergency ward (EW), the situation is even worse; since EW physicians are exceedingly busy, the admitted patients are usually sent to the wards without medication orders being entered into the system. In one head nurse's rough estimation, one out of every five patients admitted daily is from the emergency ward. In these instances, because nurses are not formally allowed to start a patient on medication with only a paper-based prescription, they are forced to call the physician who admitted the patient to the ward or to find another physician who can enter the patient's medication into the system. Until they can do this, nurses sometimes ask patients to use their usual medications, which they normally bring with them to the hospital. If a patient needs to be started quickly on a new medication, nurses do not wait for the prescription label to arrive; they begin to administer that medicine out of their ward supply. If the medication is not in stock, they will borrow it from another ward.

With respect to the formal way of communication, prescription labels and AMO lists can be considered as links that transfer data from the electronic to the paper-based system. Prescription labels, however, have many shortcomings as an effective method of communication. As shown in Figure 1, prescription labels are small pieces of black and white paper that contain a great deal of information in small print. This makes nurses potentially prone to errors in reading and working with prescription labels. These kinds of mistakes are more likely to happen when nurses have to read and distribute many prescription labels quickly: for example, during busy shifts, when a patient is transferred from one ward to another, or when prescription labels are held up by physicians. When the names of patients are similar, it is highly probable that prescription labels get mixed up and a wrong one is placed on the wrong patient's Kardex-card. It is also possible that the names, routes of administration, and timing of the drugs are misunderstood or misinterpreted. Many of these errors are normally discovered and corrected during the evening or night shifts when patients' Kardex-cards are checked against their medicine cabinet and AMO lists. However, other mistakes may not come to light for some time and patients may receive wrong medications or incorrect doses.

> "During the night shifts, nurses distribute 24 hours' worth of patients' medications into their medication cabinets. After 24 hours the cabinets have to be empty, but sometimes they are not. Then we have to check [with AMO lists and Kardex-cards] and see what happened and what the reason is. Sometimes you discover that some of the stickers are missing, or are put in wrong positions or on wrong Kardex-cards. But sometimes you have no idea why it is so." [A head nurse]

To avoid these kinds of errors, nurses pass their logbooks on to colleagues during a shift change or they put a notice in the nursing station which says, for example, "Patients with similar names have been admitted to the ward". Recently, nurses have also been instructed to check both the patients' names and their date of birth before administering medications.

Nurses cannot easily communicate feedback and comment on the prescription process. Physicians, especially junior physicians and residents, may make prescription errors that are detected by nurses. However, informing physicians about these errors has become difficult since the CPOE system was implemented. Because nurses receive prescriptions asynchronously, the only way for them to correct these errors is to pick up the printed prescription labels and then find the prescribing physician directly or by phone.

There is an increased possibility that part of a patient's medication data will be lost during medication activities. Physicians are used to complying with the medication timing offered by the system. However, in routine medication work, nurses may consider that some drug administration plans do not fit in with their ward routine or with the conditions of the patients, and they have to adjust them, especially with regard to timing. Therefore, nurses simply put cross mark over the timing indicated on prescription labels and on the Kardex-card they write down the administration timing that is more suitable. However, physicians are rarely informed of these alterations in patient medication plans and the changes are not registered in the CPOE system, especially if they are temporary or due to ward routine. As a result, this information is not practically accessible and is lost to the physicians. It is the same for PRN[1] medications. There is no way for physicians to know through the CPOE system how much of a PRN medication a patient received unless they ask nurses or look at the nursing records. Another common area where information can be lost in the medication process loop concerns physicians' verbal instructions. Nurses normally fill verbal orders, and they register them in nursing records and/or on the appointment form to remind physicians to enter them into the system. However, nurses sometimes forget to remind physicians, especially if they are delayed and a shift change takes place. Verbal orders are considered important in facilitating the medication workflow, especially when physicians do not have access to the CPOE system. They represent an informal method of order communication that is still common between physicians and nurses and helps them to build interoperability, though at the same time running the risk of information loss.

[1] PRN means 'whenever a patient needs it'.

Table 5. Workflow problems due to interoperability problems introduced by the CPOE system into nurses' medication workflow; the system-related reasons for the problems; and nurses' compensatory actions.

Workflow problems due to problems in interoperability	Reasons	Compensatory actions
• In routine work, nurses receive prescription labels late. • Nurses cannot be sure why a patient's medication plan has been changed. • Nurses cannot be sure when physicians are going to issue prescription labels. • Physicians may change their verbal medication orders. • Nurses have to read and distribute stickers quickly, making them more vulnerable to mistakes in reading (e.g. confusion between look-alike names, etc.), distributing the labels, and executing the orders. • For newly admitted patients, especially from the emergency ward, nurses are often confused about medication orders, since they are not entered into the system. • Certain information that cannot be registered quickly in the system is lost. • The timing shown on prescriptions is not compatible with a ward's routine.	• Logging on to the system and entering medication orders is time consuming. • Entering medication orders into the system for the first time is time consuming. • Prescription labels for different patients and by different doctors are printed in random order. • Too much information is presented on a small piece of paper (prescription label) in black and white. • Nurses cannot work with the system and their information is not integrated into the system. • The system fails to synchronize the prescription phase with other medication process phases.	• Nurses frequently have to interact with physicians either directly or through phone calls. • Nurses frequently have to check the system's printer. • Nurses hand over each other's prescription labels to colleagues. • Nurses have to accept verbal orders from physicians. • Nurses warn each other about existing patients with look-alike names in the ward and have to double-check each other's medication work. • Nurses do not wait for the prescription labels and begin medication work based on the notes they took during medical rounds. • Nurses have to find a physician to enter the newly admitted patients' medication orders into the system. • Nurses borrow out-of-stock emergency medicines from other wards. • Nurses have to request patients to use their usual medications until a physician enters their new medications into the system. • Nurses write down verbal instructions on paper-based forms both for legal purposes and to remind physicians to enter them into the system. • Nurses have to change administration plans according to their work routine or to the patients' medical condition.

6. Analysis

An analysis of the questionnaires showed that the layout of the medication orders was not significantly changed in comparison to the paper-based medication system. Likewise, the interviews showed that nurses claim the presentation of information on prescription labels causes them to make mistakes in reading and executing the prescription orders. The surveys showed that nurses did not consider data arrangement and administration records reliability to be significantly changed. Likewise, the interviews demonstrated that during medical rounds nurses and physicians usually use an AMO list instead of a Kardex-card to inform them as to what medications patients use. Physicians did not have access to administration data and felt that they had lost control of the monitoring phase of the medication process, while nurses believed that they had little influence on physician's prescriptions. Nurses' ad hoc adjustments and adaptation to administration plans were rarely communicated to physicians. Moreover, the interviews revealed restrictions in synchronization and coordination between physicians and nurses after the CPOE system was implemented. As a result, the shift from one phase of the medication process to another was not as smooth as previously, requiring nurses and physicians to remind each other to begin and to fulfill their medication tasks. Nurses, for example, have no idea when physicians issue prescription labels and for what reasons; this requires them to call physicians frequently. For their part, physicians cannot be sure whether the prescriptions that they entered into the system were picked up by nurses; this requires them to inform nurses by a phone call or in face-to-face communication.

The qualitative research showed that nurses have problems in communicating information to physicians, including their feedback on prescriptions (syntactic interoperability problem). More importantly, it became clear that despite improved clarity and completeness (improved syntactic interoperability), medication orders in many instances do not accomplish their desired intentions, i.e. semantic interoperability problem. The interoperability problems have produced problems at medication workflow and required nurses and physicians to develop workarounds and to make extra efforts to solve the problems.

7. Discussion

Our study has shown that although the system improved nurse-physician syntactic interoperability at the prescription phase of the medication process, at the same time it produced problems at the administration and monitoring phases. This interoperability was problematic throughout; even in the prescription phase there were semantic interoperability problems due to a problematic information flow from nurses to physicians. The interoperability problems led to problems at medication workflow. To compensate for workflow problems and to facilitate interoperability, many informal interactions, ad hoc rules, and informal practices (workarounds) were developed. In a situation involving damaged interoperability and a different, informal use of the system, there is considerable potential for nurses and physicians to make mistakes.

The implementation of a CPOE system is critical for its successful application, and implementation problems can explain many of the system's counterproductive effects on healthcare processes [10]. However, there are also other, and mostly hidden, factors amounting to adverse influences of a CPOE system. We evaluated a CPOE system after approximately three years of its successful implementation and use, and found many interoperability problems that led its users to adopt error-prone compensatory strategies. We have seen how the devised workarounds in working with the system may predispose nurses and physicians to err in their practice.

The developing workarounds in working with IT systems and their effects is a growing concern in the field of medical informatics. These compensatory reactions are meant to repair workflow breakdowns and to facilitate work process [33, 34]. They however can increase cognitive efforts and lead to instability, workload [33], and compromise patient safety [35]. Vogelsmeier et al. [34] evaluated the mechanisms that led to the development of workarounds during the implementation of an electronic administration record system, and they conclude that an understanding of the workarounds is an important consideration in comprehending the risk to medication safety. In this study, we have seen that many of them can be a potential source of medication errors. Although we did not quantify the errors due to the developed workarounds, we brought into attention the conditions that may induce medication errors. Such conditions are not recognized in the ordinary methods of evaluating an information system, unless the effect of the system on the entire medication process is considered and the implementation environment is seen as a dynamic condition that can compensate for many of the system's shortcomings. In this dynamic environment, many of the potential errors due to the system application are corrected by care providers before they reach to patients. Those potential errors are posing grave risk to patient safety while they are not usually recorded in any patient care information system. Moreover, the recorded information does not necessarily represent the real events as the records can be changed or adjusted on ad hoc base. Recording errors retrospectively, therefore, can never be representative of the real condition and the real risk to patient safety.

Workarounds and their impacts can be escalated if they are not recognized and their sources are not managed properly [33]. Practically, it is not possible to stop workarounds, since without them a system's work grinds to a halt [36]. The sources of workflow breakdowns in working with a system have to be recognized and improved if workarounds have to be managed. Interoperability problems in our study were the main source of many workflow breakdowns, and those problems emerged because prescribing was not considered within the interconnected phases' loop of the medication process. Appropriate communication mechanisms, therefore, were not designed into the CPOE system to support the necessary level of integration between nurses' and physicians' tasks throughout the medication process. Printing medication orders turned out to be a problematic mechanism for integrating information from the prescription phase into other phases of the medication process, and the possibility to integrate information from other phases into the prescription phase was also not designed into the system. Although many of those problems can be addressed in a system redesign, performing required technical adjustments to commercially-sold systems is usually hard and time consuming process. Therefore, in many cases organizational appropriations to improve nurse-physician interoperability are the most feasible improvement measures. Moreover, the nature of our findings emphasize on the importance of polices and decisions in post implementation period that may cause more interoperability problems for a system users, persuading them to devise unsafe workarounds.

We believe that interoperability problems are not specific for the system we implemented or for the environment that we studied. Similar concerns about nurse-physician communication and collaboration have been reported in evaluating CPOE systems being implemented in different locations [11, 13, 37]. Our findings in this study are also in line with Koppel et al. [4] and Beuscart-Zephir et al. [13], in the sense that they help to understand and to improve the impact of hidden factors that can lead to a CPOE system having unintended negative effects [38]. Therefore, evaluating the impact of a CPOE system on interoperability can be used to inform about the effect of the system on coordination and collaboration throughout the medication process and, as a result, about whether the system reduces errors in practice.

Healthcare systems are now moving from paper-based to electronic. As full automation of many healthcare processes, such as that of medication, is extremely difficult, if not impossible, incremental IT interventions like CPOE systems are inevitable. The incremental steps however run the risk of care processes disintegration. Several promising health information technologies, such as automated bar coding and electronic administration registration systems, may help better medication data exchange between nurses and physicians. However, they need to take into account that technology per se is not a panacea and always has its own disadvantages [39, 40]. There is a great possibility that the interoperability of healthcare providers will be damaged if such systems do not integrate appropriately into the entire process. Therefore, the important yet less often discussed question is: how should these systems be designed, implemented, and integrated into highly cooperative settings and not hinder healthcare work by, for example, creating automated islands?

Our study had several limitations. As with any survey study, a self-selection bias was inevitable. The survey respondents, for example, may have more positive attitude toward the intervention and to be more motivated than non-respondents. Another important limitation of survey study concerns the self-report bias. Considering the possible effect of these biases, we deliberately designed a qualitative study to test the validity of the quantitative findings. The system we evaluated did not have bedside prescription feasibility. Although this deficit compounded interoperability problems, we have ignored them in this paper. There was no central Electronic Patient Record or electronic medication administration recording system to register and retrieve whole medication-related data, which could provide more live view of medication data and reduce the nurse-physician interoperability problems. And finally we did not quantify errors caused by interoperability problems.

8. Conclusion

We focused on the effect of a CPOE system on nurse-physician interoperability in the medication process and found many conditions where working with the system produced interoperability problem and contributed to error-prone practices. To reinforce interoperability, the system needs to support integrating the work of physicians and nurses throughout the whole medication process. This means that as well as a mechanism to integrate physicians' medication orders into nurses' medication management systems, there must be an appropriate mechanism for nurses to integrate their information into CPOE systems. Moreover, our study shows that interoperability between care providers can be used to evaluate the impact of an information system on the highly collaborative work such as medication process.

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CHAPTER 3

Impact of a computerized physician order entry system on nurse-physician collaboration in the medication process

Habibollah Pirnejad, Zahra Niazkhani, Heleen van der Sijs, Marc Berg, Roland Bal

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A b s t r a c t

Background: Due to their efficiency and safety potential, Computerized Physician Order Entry (CPOE) systems are gaining considerable attention in in-patient settings. However, recent studies have shown that these systems may undermine the efficiency and safety of the medication process by impeding nurse-physician collaboration.

Objective: To evaluate the effects of a CPOE system on the mechanisms whereby nurses and physicians maintain their collaboration in the medication process.

Setting and Methodology: Six internal medicine wards at the Erasmus Medical Centre were included in this study. A questionnaire was used to record nurses' attitudes towards the effectiveness of the former paper-based system. A similar questionnaire was used to evaluate nurses' attitudes with respect to a CPOE system that replaced the paper-based system. The data was complemented and triangulated through interviews with physicians and nurses.

Results: Response rates for the analyzed questions in the pre- and post-implementation questionnaires were 54.3% (76/140) and 52.14% (73/140). The CPOE system had a mixed impact on medication work: while it improved the main non-supportive features of the paper-based system, it lacked its main supportive features. The interviews revealed more detailed supportive and non-supportive features of the two systems. A comparison of supportive features of the paper-based system with non-supportive features of the CPOE system showed that *synchronization* and *feedback* mechanisms in nurse-physician collaborations have been impaired after the CPOE system was introduced.

Conclusion: This study contributes to an understanding of the affected mechanisms in nurse-physician collaboration using a CPOE system. It provides recommendations for repairing the impaired mechanisms and for redesigning the CPOE system and thus for better supporting these structures.

1. Introduction

Computerized Physician Order Entry (CPOE) systems are being pushed as a substitution for paper-based medication systems, especially because of the promise that they would increase the efficiency and safety of the medication process. Physicians and pharmacists, in particular, are increasingly expected to work with these tools, especially in in-patient settings [1]. Many recent studies have shown that these systems improve the medication process and reduce medication errors [2-7]. One of the main reasons that CPOE systems are believed to improve the medication process is that they support better data communication between care providers [5, 8-10].

However, there have also been concerns in the literature about the potential disadvantages of these systems [11, 12]. Studies have suggested that CPOE systems may undermine nurse-physician communication and collaboration in the medication process [13-16]. Likewise, it is suggested that CPOE systems may jeopardize patient safety and the efficiency of the medication process through hidden side-effects that cannot be easily discerned by conventional research methods [12, 13, 17, 18].

Recent socio-technical studies have shown that one important reason for the unintended negative effects of CPOE systems is that they change the nurse-physician communication mode from synchronous to asynchronous [13, 14]. This in turn negatively affects nurse-physician collaborative medication work [19, 20]. Understanding the *mechanisms* whereby the nurse-physician collaborative work is affected by a CPOE system might therefore offer clues about how to manage the side effects of the changes that have taken place and/or how to adapt the system appropriately. Thus far, however, these mechanisms have not been sufficiently evaluated in the literature.

This study evaluated the medication work support of a CPOE system comparing it with that of a paper-based system. By analyzing the reasons the two systems were considered to support or not support the medication process, we sought to answer two following questions: Which mechanisms in nurse-physician communication are affected by the switch from a paper-based to a CPOE medication system? How do the affected mechanisms impact nurse-physician collaborative medication work? Both quantitative and qualitative study methods were used to determine what nurses and physicians consider to be supportive or non-supportive features of either system.

2. Theoretical background

Classic medication work in in-patient settings is a dynamic process of highly collaborative tasks. It consists of various phases – prescription, transcription, procurement, dispensing, administration and monitoring – and involves different hospital care providers, in particular nurses and physicians. In this collaborative ensemble, medication tasks are integrated through applying mechanisms that collectively can be called *articulation* work. Articulation work is necessary to assure that physicians' and nurses' collective efforts "add up to more than discrete and conflicting bits of accomplished work" [21] . The central figure in planning patient medication therapy is the physician but "the key actor in articulation drama is the nurse" [21].

Analyzing collaborative work in designing and evaluating information systems is necessary but a complex issue [22]. Highly collaborative work, such as the medication work, inevitably raises differences with regard to care providers' perspectives on structure and organization of the work [23]. This has two immediate implications for work analyzing. Firstly, it makes task decomposition problematic. This breaking down of the task structure is necessary for the articulation of tasks among different divisions of labor [21] and for evaluating how successfully an information system supports the work [22]. Secondly, it produces different views on the significance and meaning of the various artifacts associated with a task [22]. Taking into account these difficulties in analyzing collaborative work, Healey et al.[23] argue for focusing on communicative processes instead of on notions of tasks or goals as basic units of analysis.

Effective communication, as Strauss et al. [21] argue, is in fact a generalized articulation strategy and thus a generalized collaborative strategy among healthcare professionals. However, effective communication is not simply an information-transaction process; it is a process that centers on coordination between the communicators and on establishing, testing and maintaining relationships [18, 24, 25]. This requires physicians and nurses to attain, more or less, a shared understanding of the communicated information in the course of their collaborative work [26]. Therefore, effective communication can be defined as leading to a *mutual intelligibility* of the communicated information and thus lead to a proper work articulation between nurses and physicians.

Interoperability is defined as 'the ability of parties, either human or machine, to exchange data or information' [24]. In this study we applied an extended definition of interoperability as it pertains to nurse-physician mutual intelligibility in their medication-related communication processes, either directly or through using a paper-based or an electronic medication system. Similar to the discussion by Bannon et al.[26] about *common information space*, the nurse-physician interoperability in this study provides a framework for our understanding of the properties of medication-related information that crosses between nurses' and physicians' professional boundaries and articulate their medication work. Such an understanding of interoperability can be used to highlight the effort that is needed to bring information from one community into a shared arena [23]. Moreover, it can provide a framework for analyzing the role of an information system in supporting medication work. If an information system helps nurses and physicians to perform an interoperable information exchange in their work, it will also support them to articulate their work and to collaborate better.

3. Study context

The study was conducted in a Dutch tertiary academic medical centre with 1237 beds. Before implementation of a CPOE system, a paper-based medication system, named TIMED, was used by both physicians and nurses in the internal medicine wards. In this paper-based system physicians wrote their prescriptions on the pre-printed forms. Nurses then translated the prescriptions into suitable administration times and dosage forms according to ward routines. They registered data on an administration form, either by putting on it the labels of the administered drugs or when the labels were absent by writing the name of the drugs, and then signing the form (Figure 1). Each day a new administration form was used and was placed next to the transcribed order form on a patient's chart.

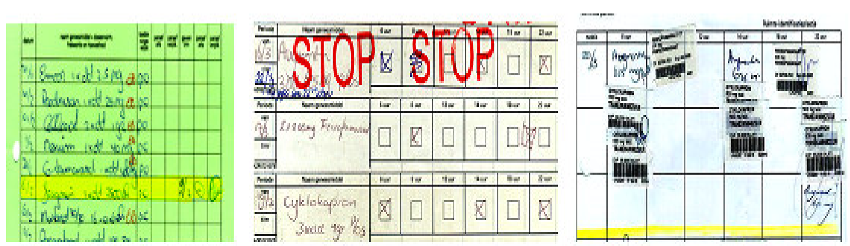

Figure 1. From left to right: prescription form, transcription form and administration registration form in the paper-based medication system (TIMED).

A commercially sold CPOE system, *Medicatie/EVS®*, was implemented in 34 wards of the medical centre between September 2003 and March 2005. The system allows physicians to prescribe electronically and has the capability to recognize and to alert on drug overdoses, interactions and duplicated orders. The system is integrated into the Hospital Information System (HIS) and the

Electronic Patient Record so that physicians can navigate from one system to another and browse patient data. The system was made available in physicians' offices as well as through every hospital computer that was connected to the HIS.

Once a physician enters a medication order into the system, clicks on the print button and/or logs out, the prescription – in the form of a 3.5cm ×10cm adhesive label – is printed out on a special printer (see Figure 1 in chapter 2). For administration registration and distribution purposes, nurses use a paper-based medication card, which is illustrated in Figure 1 in chapter 2. The prescription labels are fixed to this card. Nurses can look at patients' current medication data in the CPOE system and make printouts of them, and they can request the necessary drugs from the pharmacy department; however, they cannot make changes to patient medication data in the system.

The prescription labels contain a variety of information including patient's name, physician's name, ward code and so forth. At the bottom of the label is a small area for necessary notes and remarks that nurses need to bear in mind while administering the medication. Each nurse picks up her or his own patients' prescription labels from the printer and places them on the administration cards. Next to each label on this card are empty spaces where nurses register data and sign whenever the medication is given to patients. Commonly used medications are stored in each ward's supply of stock and if a prescribed item does not exist in the ward stock it is ordered by HIS from the pharmacy department. Except in special circumstances, nurses are not allowed either to administer drugs from the ward's stock or to order out-of-stock medications from the pharmacy department unless they have the relevant prescription labels at hand.

4. Methods

Qualitative and quantitative methods were used to evaluate the effect of changing from a paper-based prescription system to an electronic one on nurse-physician communication and collaboration. For two reasons we focused our study more on nurses. First, considering the different stages of the medication process, it can be realized that nurses play a considerable role in almost all phases of the medication process. Second, because of their wide spread presence throughout the medication process, nurses play a pivotal role in articulating different care providers' tasks. Figure 2 represents the frame of reference used in this evaluation study. Transition from a paper-based to a CPOE system alters communication and the mechanisms whereby nurses and physicians attain interoperability, which is represented by the question mark in Figure 3 [13, 14]. These mechanisms in turn affect nurses' and physicians' interoperability, work articulation and finally their collaborative work. Evaluating the changes in nurse-physician medication work after the implementation of a CPOE system can establish which mechanisms in nurse-physician communication have changed.

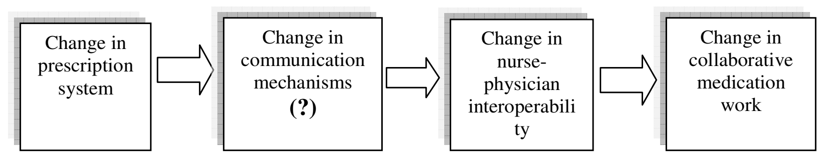

Figure 2. Change in the medication system changes communication mechanisms which in turn affects establishment of interoperability between nurses and physicians and subsequently the collaborative medication work.

4.1. QUANTITATIVE RESEARCH

The quantitative evaluation took place in all six internal medicine wards, with a total number of 174 beds. The internal medicine wards were selected on the grounds that the medication-related work of nurses and physicians in these wards is considerable. A questionnaire was used to record nurses' attitudes towards the effects of the former paper-based system on their medication work and communication prior to implementation of the CPOE system in November and December 2003. In the same manner, a second [somewhat different] questionnaire evaluated nurses' attitudes towards the CPOE system five months after its implementation in April 2004. All 140 nurses active in the internal medicine wards were included in these surveys. In each ward the head nurse was asked to distribute the paper-based questionnaires, to motivate the nurses to fill them in, and then to collect and return the completed forms. We followed the returning of the filled questionnaires through head nurses 1, 3 and 5 months after their distribution. 76 questionnaires related to before and 75 questionnaires related to after implementation were returned. All completed pre-implementation questionnaires and 73 of those completed post-implementation were useable for the analysis.

The original questionnaires were in Dutch language and contained 28 and 40 questions, for evaluating the paper-based and CPOE systems respectively, and were either in multiple-choice or five-point Likert scale format. The questionnaires were optionally anonymous, and covered different topics ranging from nurse satisfaction with the medication systems, the systems' usability and their effects on nurses' medication work. In developing the questionnaire already published surveys about CPOE systems such as [27] were considered and the understandability of the questionnaires were checked with two informant nurses. Three questions featured in both questionnaires were selected to report in this paper as they were evaluating the support of the two medication systems on medication work and since they were complementing our qualitative research. The remainder questions from the questionnaires will be reported in other papers.

The first question asked nurses whether their current medication system supported their work process. Three possible options were provided for this question: Yes, No and Unsure (Figure 3). The next two consecutive questions asked nurses about the reasons for their answers. Those who marked 'Yes' in the first question were requested to answer the second question, which named a number of supportive features of the two systems. Nurses who marked 'No' in the first question were requested to answer the third question, which named a number of non-supportive features of the two systems (Table 2). Respondents who marked the 'Unsure' had to answer both the second and the third questions. In those two questions, it was possible to choose more than one answer. The Mann-Whitney U-test was used to analyze the first question in both pre- and post-implementation questionnaires. More insight into the result of the first question was provided by the descriptive analysis of the questions 2 and 3.

4.2. QUALITATIVE RESEARCH

Between November 2006 and June 2007, we conducted 15 interviews with nurses (n = 9) and physicians (n = 6) who had at least two years experience working with both systems. The interviews were carried out by the first and second authors who have background on medicine and Health Informatics. The interviews were in-depth, semi-structured, one-to-one and face-to-face; each one lasted 45-60 minutes. The focus was on the effect of the two systems on communication and collaboration between nurses and physicians in their daily medication work. The interviewees were asked whether or not the CPOE system supported their medication work and about the reasons behind their answer. The interviewees' tasks in each stage of the medication process were questioned and the impact of the systems on their tasks was discussed. In each topic, the interviewees were asked to compare their current situation to the paper-based system. The emergent themes and ideas were discussed in more depth with the interviewees. This part of the research, therefore, triangulated our quantitative methodology in the sense that the interviewees were asked the same questions as in the quantitative survey, enabling them to substantiate their answers and to relate them to their role in medication work. The data was also triangulated because both nurses and physicians were asked the same kinds of questions.

The interviews were voice-recorded and transcribed. The transcriptions were reviewed, coded based on Bowling [28], and analyzed independently by the first and second authors. The coding scheme included differentiation between those features that were considered supportive from features that were considered non-supportive to nurses' and physicians' medication work. The mixed features were considered in both supportive and non-supportive categories at the same time. We excluded those non-supportive features related to impossibility of bedside prescription by the CPOE system. The inter-rater agreement between the two reviewers was assessed by calculating Cohen's Kappa.

5. Results

5.1. QUANTITATIVE RESULTS

Overall response rates were 54.3% (76/140) for the pre-implementation survey and 52.14% (73/140) for the post-implementation survey. Two of the pre-implementation questionnaires did not contain answers for questions analyzed in this study, therefore, they excluded from the analysis process. Demographics of the respondents in both surveys are presented in Table 1. The majority of the respondents were female, practicing nurses and between 24-33 years old.

The analysis of the first question using the Mann-Whitney U test showed a statistically significant difference between nurses' attitudes in pre and post-implementation ((P= 0.048). The descriptive analysis showed that almost the same percentage of nurses in the two groups believed that both systems supported their medication work (60.5% for the paper-based system and 68.5% for the CPOE system) (Figure 3). However, a substantial percentage of the nurses in the paper-based system believed that this system did not support their medication work: 32.9% vs. 2.7%. On the other hand, a high percentage of nurses in the CPOE system were unsure as to whether the CPOE system supported their medication work: 28.8% vs. 3.9%.

Table 2. Demographics of the respondents in pre-implementation (N=74) and post-implementation (N=73) surveys.

		Pre-implementation (Paper-based)		Post-implementation (CPOE system)	
		Frequency	Percentage	Frequency	Percentage
Gender	Male	14	18.9	12	16.4
	Female	61	81.1	60	82.2
	Missing data	0	0	1	1.4
Age	<=23 years old	11	14.9	13	17.8
	24-33	24	32.4	25	34.2
	34-43	16	21.6	15	20.5
	44-53	20	27	18	24.7
	>=54 years old	2	2.7	1	1.4
	Missing data	1	1.3	1	1.4
Professional position	Practicing nurse	61	82.4	55	75.3
	Nurse manager	3	4	6	8.2
	Nurse student	8	10.8	10	13.7
	Other	2	2.7	1	1.4
	Missing data	0	0	1	1.4

Question 1. Does the TIMED/CPOE system support your medication work process?				
	TIMED		CPOE	
	Count (74)	Percentage (100)	Count (73)	Percentage (100)
Yes	46	60.5	50	68.5
I am not sure	3	3.9	21	28.8
No	25	32.9	2	2.7

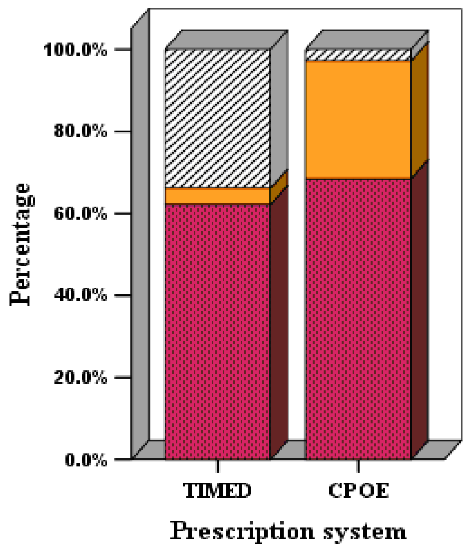

Figure 3. This diagram represents the percentage of nurses in the pre- and post-implementation studies who believed that the paper-based or the CPOE system supported their medication work process.

As reasons for their answers, the respondents referred to different features of the two systems. Table 2 shows the frequency of the reasons chosen as support of medication work by either the paper-based or the CPOE system. This support concerning the paper-based system was rated mainly because the system made it possible to view administration records as well as prescription data (71.4%) and because it provided a clear overview of patients' current medications (53.1%). The CPOE system, on the other hand, was considered to support nurses' medication work mainly because it improved data legibility (74.6%) and it provided a clear overview of patients' current medications (67.6%).

Nurses referred to various non-supportive features of the two systems as reasons that they did not support their medication work. As shown in Table 2, nurses believed that the paper-based system did not support their medication work mainly because of the illegibility of handwritten medication data (64.3%), poor drug overview (46.4%), and also because the medication process by using the paper-based system was considered slow (46.4%). A similar concern about the CPOE system had mainly to do with dependency on the computer (56.5%), the fact that there is no possibility to check what medication had already been administered to a patient (52.2%) and there is no possibility for nurses to correct physicians' prescription errors (43.5%).

5.2. QUALITATIVE RESULTS

The chance corrected agreement between the two independent coders was good (κ= 0.76; 95% confidence interval [CI], 0.86-0.66). Opinions were mixed, and provided us with the reasons why it was felt a system supported or failed to support the medication work. The representative quotes from nurses and physicians for both systems are presented in Tables 3 and 4. They were in many respects similar to the quantitative results, and offered more insight into them. For example, they explained how the non-supportive features of the CPOE system cause healthcare professionals to make mistakes in their practice.

Table 2 – Questions 2 and 3 and the number of times their options were rated by nurses.

Questions	Options	TIMED, N (%)	CPOE, N (%)
Question 2. Why do you think the system support your work process? (More than one answer is possible.)	• It provides clear drug overview of patients' current medication [T,C]	26 (53.1)	48 (67.6)
	• Process is speedy [T,C]	11 (22.4)	22 (31.0)
	• It is possible to correct prescription errors [T]	17 (34.7)	–
	• It is possible to take over physicians' task [T]	4 (8.2)	–
	• It is possible to check what has been administered (integrated view of prescription and administration data)[T]	35 (71.4)	–
	• Reliability of data [C]	–	32 (45.1)
	• Less different system for ordering drugs from the pharmacy department [C]	–	17 (23.9)
	• Drug-safety alerts [C]	–	22 (31.0)
	• Legibility of prescription data [C]	–	53 (74.6)
	• It is possible to order out-of-stock medications from pharmacy department [C]	–	29 (40.8)
Question 3. Why do you think the system does not support your work process? (More than one answer is possible.)	• Poor overview of patients' current medication [T,C]	13 (46.4)	5 (21.7)
	• Slower process [T,C]	13 (46.4)	4 (17.4)
	• No reliability of data [T,C]	10 (35.7)	0.0 (0.0)
	• Completely different system of ordering drugs from the pharmacy department [T]	10 (35.7)	–
	• No drug-safety alerts [T]	10 (35.7)	–
	• Illegible data [T]	18 (64.3)	–
	• It makes it impossible to order out-of-stock items from the pharmacy department [T]	7 (25.0)	–
	• It makes it impossible to take over physicians' task [C]	–	5 (21.7)
	• It makes it impossible to check what has been administered (integrated view of prescription and administration data)[C]	–	12 (52.2)
	• Less possibility to correct prescription errors [C]	–	10 (43.5)
	• Dependency on computer [C]	–	13 (56.5)

T= specific options for the pre-implementation survey, C= specific options for post-implementation survey

Table 3 – Supportive features as listed by the interviewees.

Physicians	Nurses
The paper-based system	
• Less time was needed to create prescriptions • Writing orders on paper was easier than entering them into the system • Prescription orders were less confusing for nurses • All the medication-related data was aggregated in a patient's medical chart. It was easier to browse and to find information	• Processing prescription orders was much simpler. • Allowed to advise physicians on medication form, dosage, and the timing of administration: factors that are contingent upon ward routines and the condition of the patients • More possibility for feedback on physicians' prescriptions • Possibility to write important things in different colors for emphasis
The CPOE system	
• The system has safety alerts • The system provides good assistance at the moment of adjusting and combining different medications • Patients' medication files are accessible from everywhere in the hospital; they can be looked up and changed, or new prescriptions can be added • The system provides good documentation of the prescribed items	• Prescriptions' clarity is improved • Legibility of prescription data is improved • Prescriptions are now more complete • It is clear which doctor prescribed or changed what in patients' medications

Table 4 – The non-supportive features of the two systems as listed by interviewees.

Physicians	Nurses
The paper-based system	
• Poor documentation of prescribed items • Difficult to read the illegible handwriting of other colleagues who had already attended to patients • No possibility to check interactions and overdoses	• Illegible handwriting of physicians • More mistakes in writing the name of medications and doses by hand • Transcribing prescriptions took time • It was not always clear which physician had changed a patient's medication
The CPOE system	
• Too much information on prescription labels confuses nurses • Nurses read the prescription labels quickly and make mistakes in executing the orders (especially with respect to what has been written in the remarks place) • The number of questions from nurses to physicians with respect to medication has increased following implementation of the system • Nurses are demanding that physicians issue prescription labels quickly • It is impossible to find out through the system what medication has been administered to a patient • Entering patient medication data into the system is time consuming, especially the first time and in the case of a newly admitted patient who uses many other medications • We cannot be sure whether nurses have picked up and filled a prescription order	• Difficult to correct physicians' prescription errors • We have no idea when a physician is going to issue prescriptions through the system • We have to call physicians frequently because they issue the prescription labels late. This causes problems in our work, especially if the prescribed medication has to be ordered from the pharmacy department • We cannot be sure why a medication is changed or stopped by a physician if he or she do not inform us directly • There is too much information in prescription labels, which sometimes causes confusion in reading and executing the orders • Prescription labels for different patients and by different doctors are printed in a mixed order (i.e. if A and B represent different patients' prescription labels, they may be printed in a sequence like: AABAABBA). This is confusing, and nurses easily make mistakes in picking up and executing their patients' medication orders • All information on the prescription labels is printed in small letters in black and white, which easily causes nurses to make mistakes when reading the labels • The administration timing on prescription labels is not in accord with our ward routine. We have to change the timing ourselves

6. Analysis

Nurses rated the two systems with respect to the options 'No' and 'Unsure' very differently, which caused the Mann-Whitney U test to show a significant difference between the two groups. More nurses in the paper-based system than in the CPOE system believed that their medication system did not support their medication work. In contrast, more nurses in the CPOE system than in the paper-based system were unsure as to whether their medication system supported their medication work. These differences can be explained in two different ways. First, nurses had been using the paper-based medication system for a long time, while the CPOE system was relatively new at the time of the survey, which took place five months after implementation. Thus, some respondents would have needed more time to be certain about the system's support capabilities. Second, the CPOE system had a mixed effect on the medication work, which made it difficult for some of the nurses to be able to answer definitively.

An analysis of the second and third questions demonstrated that the CPOE system indeed had a mixed effect on the medication work. The main non-supportive features of the paper-based system were the legibility problem of medication data, the poor overview of patients' current medication data and the slower process time. These were the main reasons that the CPOE system was considered to support the medication work. On the other hand, the paper-based system was seen to support the medication process because it offered an integrated view of administration and prescription data and also made it possible to correct physicians' medication errors. The lack of these features in the CPOE system was considered the main reason that it did not support nurses' medication work.

The qualitative results were in line with the quantitative findings, upon which they also elaborated. It is clear that moving from the paper-based to the CPOE system had positive and negative impacts on nurses' and physicians' medication work. Many of the paper-based system's non-supportive features were improved by the CPOE system. And, more useful features such as safety alerts and the possibility for physicians to prescribe electronically from everywhere in the hospital greatly benefited the prescription phase and improved the medication process. Nevertheless, nurses and physicians listed many non-supportive features of the CPOE system as well.

7. Discussion

Many of the CPOE system's non-supportive features are produced since changing prescription system induced problems in nurse-physician interoperability. Comparison of the CPOE system's non-supportive features with the supportive features of the paper-based system demonstrates that two important mechanisms in nurse-physician communication are damaged: *synchronization* and *feedback*. Despite the clarity and completeness of prescription labels, damaged feedback mechanisms made it hard for nurses and physicians to build interoperability upon the prescription data. Instead, the prescription labels caused confusion for nurses. And because of the impaired feedback mechanism, physicians had no idea whether the instructions they had given through the system were picked up and carried out at the right time and in the correct order. Similarly, due to synchronization problems, nurses had no idea what would come out of the system's printer and when. Because they could not be sure why the prescription plan had been changed, they even hesitated to carry out any orders that contained changes to a patient's medication plan. And, because of poor synchronization, nurses and physicians were not aware of each other's work progress, leading them to constantly remind each other to perform tasks, for example through repeated phone calls.

The prescription phase in the medication process is not merely a time during which physicians give the prescription orders, either through paper-based order sheets or a CPOE system. Rather, it is a critical moment in the whole medication process. During this phase nurses and physicians synchronize their next steps, share knowledge about a patient's condition and medication plan, and provide feedback on each other's tasks; as a result, they build interoperability and integrate their work. In our study, the old paper-based system made it possible for nurses and physicians to interact directly and efficiently with regard to a patient's condition, medication orders and medication administration data. In this way, they were able to build interoperability, contribute to a common decision about prescription orders and be aware of each other's next steps in the patient's care trajectory. However, the CPOE system has a physician-advantaged design that promotes asynchronous communication and separates the work of physicians from that of nurses. Both are required to work with completely different systems, making it difficult to integrate their medication-related information and to build interoperability. They can no longer synchronize and provide mutual feedback, and thus face challenges in coordinating and integrating their work. The CPOE system as such is unable to take over the articulation work central to creating interoperability.

Various studies on the implementation of CPOE systems in different environments have reported that it generates communication problems between nurses and physicians [13, 14, 29, 30]. However, few of these studies have evaluated the mechanisms affected in nurse-physician communication, and even fewer have raised suggestions to help reduce this unintended impact [13, 14]. Our study has shown that in order to minimize unintended consequences in conditions (such as those in our study environment), where a CPOE system has already been implemented, synchronization and feedback mechanisms between nurses and physicians need to be reinforced through different structures. Nurses and physicians must be aware of the negative impacts of the system on their communication. Both groups should be educated with respect to the methods they can use to improve the impaired synchronization and feedback and to avoid any practice that may increase this impairment. For example, they have to be persuaded to discuss with each other any change in patients' medication. Synchronization problems may increase by the fact that the system makes it possible for physicians to perform their prescription task without attending the ward or to a patient's bedside and without doing necessary coordination with nursing staff. The frequent use of this feasibility, therefore, is not recommended. Building safe feedback mechanisms in many cases requires direct nurse-physician communication. If it is not planned for, however, synchronous communication can interrupt nurses' and physicians' work [31]. For this reason, physicians are still advised to do their medical rounds together with nurses.

Damaged synchronization and feedback mechanisms also have serious implications for patient safety. Although the system offered good decision support for choosing and adjusting medication types and doses, medication errors, even in the prescription phase, were still an important concern. One reason was that the CPOE system made it difficult for physicians to have an integrated view of administration data during the prescription phase. For example, the timing of prescriptions was not usually in accord with ward routines, and nurses had to change the timing without it being adjusted in the system. Moreover, because the medication process was considered to have become more complex after the implementation, nurses could not correct physicians' prescription errors as easily as in the paper-based system. Likewise, confusion, uncertainty and misunderstanding about prescriptions' contents were prevalent among nurses after they switched to the CPOE system; this caused nurses to err in their administration and monitoring practice. However, further evaluations are necessary to detect and quantify these errors.

Our study also has design implications for the CPOE system. Printout-prescriptions are still an output of many of these systems, and we noticed that a number of the problems encountered in this study were the result of printing prescription orders. In our study environment, the idea of printing prescriptions turned out to be problematic, and to compound the synchronization difficulties. We suggest that the system be changed so that the responsibility of printing the prescription orders is left to nurses and that the medication orders are no longer printed by physicians. In this way, whenever a physician creates orders in the system they will be visualized for nurses on the system's screen, and will remain pending until nurses log into the system, confirm the prescriptions and print them out. As a further safeguard, the color of the printed orders, for example, can change within the system, thereby informing the prescribing physician that the order has been picked up. Moreover, nurses should be authorized to log into the system and to change the administration timing of the prescription orders so as to fit in with ward routines before they are printed. In this manner, changes in administration timing by nurses would be recorded in the system and be visible to physicians.

This study had strong points, with the pre- and post-implementation setting forming a substantial element. Moreover, the quantitative data were triangulated and complemented by qualitative research. However, it also had its limitations. Interviews regarding the paper-based system were carried out almost two years after it had been replaced by the CPOE system. This made it possible that nurses and physicians did not accurately remember details about the former paper-based system. In addition, the study environment did not have any Electronic Medication Administration Records or Bar Coded Medication Administration systems integrated into CPOE system.

8. Conclusion

Our study demonstrated that both the paper-based and the CPOE systems supported the medication work of nurses and physicians. However, the notion of support came from different perspectives. The CPOE system improved the main non-supportive features of the paper-based system, but it could not replace some of its important supportive features. In our study, many of the CPOE system's non-supportive features were listed because the system damaged the synchronization and feedback mechanisms between nurses and physicians. Therefore, our research contributes to an understanding of the mechanisms through which a CPOE system alters collaborative medication work. Certain important points were recommended with relation to repairing the damaged mechanisms and to designing the system in a way that better supports these mechanisms.

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CHAPTER 4

Building an inter-organizational communication network and challenges for preserving interoperability

Habibollah Pirnejad, Roland Bal, Marc Berg

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A b s t r a c t

Background: The ideal scenario for information technology to bridge information gaps between primary and secondary healthcare and to improve the quality of healthcare in the medication process is to build an interoperable communication network. This type of undertaking requires diverse information systems to be integrated, and central to this are the preservation of data integrity and the integration of different pieces of patient data.

Objectives and methodology: In this study, we focused on sources of challenges to the integration process and to the building of an interoperable communication network. Interviews, document analysis, and observations were conducted to evaluate the integration process in a project that involved medication data communication between primary healthcare providers (i.e., general practitioners and community pharmacists) and secondary healthcare providers (i.e., hospital pharmacists and specialist physicians).

Results: The project encountered numerous integration problems, many of which persisted even after extensive technical intervention. An analysis of the problems revealed that they were mostly rooted either in problematic integration of work processes or in the way the system was used. Despite the project's ideal technical condition, the integration could be accomplished only by applying human interfaces.

Conclusion: The main challenge to building interoperable communication network does not lie in technical integration. The real problem occurs when the technical linkage is implemented without the work processes being aligned and integrated.

1. Introduction

In the last decade, concern has grown with regards to understanding, identifying, and preventing medical errors before they harm patients [1-3]. Many of the errors are "medication errors" [1, 4] and cause considerable morbidity and mortality in different healthcare systems [5-7] . Limited or impaired access to patients' medication-related data is the frequent source of medication errors [8]. This is especially relevant when a patient is shifted from one level of healthcare to another due to problematic communication between different healthcare levels. A recent systematic review by Canadian researchers of 22 studies involving 3755 patients showed that errors made in current medication histories during hospital admission were "disturbingly common and potentially harmful to patients". Mistakes of this kind were seen in up to 67% of the studies, which were published between 1966 and April 2005 [9].

One of the possibilities that recent ICT developments have raised is to enhance the quality of healthcare by improving communication, especially across healthcare boundaries. The ideal scenario for ICT to do this and to reduce medication errors lies in building interoperable communication networks among different care providers, whereby they can work on the same set of patient data [10-14]. To accomplish this, the information systems would have to be integrated. Thus far, however, many complications (e.g., inability to integrate different parts of patient data and problems in synchronization between communicating systems) have been reported in the integration of diverse information systems and have resulted in costly but underutilized or failed projects [12, 13, 15]. Evaluations are necessary to understand more about these complications and to discover efficient and less costly integration methods.

For an integration process to succeed, it is necessary to combine diverse items of patient data stored in a variety of information systems (data integration) and to prevent data loss or distortion (preserve data integrity). Many studies thus far have evaluated the challenges inherent in the replacement of paper-based communication with IT communication networks [16, 17] or in the technical integration of diverse information systems or different standards for incorporating patient data [18]. However, as a recent systematic review revealed, the quality of data integration and the types of error detection constitute a key point that is missing from most project publications [15].

We studied an inter-organizational communication project in The Netherlands in which primary care providers, the general practitioners (GPs) and community pharmacists, shared medication data with secondary care providers, the hospital pharmacists and specialist physicians. By evaluating the attending challenges for data integrity and data integration throughout the communication network, we sought to answer the question: How are data integration and data integrity, as practical achievements of technical integration, attained in this communication network? Qualitative research methods were used to evaluate the preservation of data integrity and the integration of medication data, and to answer the research question. The study enabled us to extend our knowledge about building an interoperable communication network between different healthcare organizations and about the role of technical integration in its attainment.

2. Study environment

The study environment was Almere, a city near Amsterdam in the northwestern part of The Netherlands. As in the rest of The Netherlands, every patient in Almere has a GP as a family doctor who acts as gatekeeper between primary and secondary healthcare. Every patient also has his/her own community pharmacist who fills his/her prescriptions. At the primary care level, together with GPs, pharmacists are responsible for ensuring the safety of their patients with regard to medication.

2.1. ORGANIZATIONAL SETTING

An IT project, named TUMA[1], was launched in 2004 in the Almere region. Its purpose was to exchange patient medication records[2] between primary and secondary care providers. Almost all of the 115 GPs and the 17 community pharmacists from the primary care side were involved. Representing the only regional hospital, the Flevo Hospital, the pharmacy department was the main participant in the project.

2.2. NETWORK DETAILS

In Almere's primary healthcare setting, nearly all GPs use an information system, and all community pharmacists use information systems from the same vendor (Medicom® and Pharmacom®, respectively). There is a common server – the "Local Health Server" – for all Medicom and Pharmacom systems in the region. By sharing the server, GPs and community pharmacists have built an application-specific communication network through which they can easily

[1] TUMA stands for trans-mural exchange of medication data in Almere.

[2] This includes patient medication data as well as a summary of patient medical records.

share and work on elements of their patients' data, including medication records. TUMA is intended to connect this regional primary care network to the only general hospital in the region. The hospital pharmacy department uses an information system (Zamicom®) similar to Pharmacom, again from the same vendor. TUMA, therefore, is building a communication network in what could be called an ideal situation, as compared to other regions in The Netherlands, which are characterized by their "patchwork" of information systems [19].

TUMA's network is a "Virtual Private Network" (VPN) connecting the Local Health Server to the Zamicom server. At the center of this communication network (eHealthNet) is a Central-Patient-Index system to ensure a one-by-one match of patients' records between primary and secondary healthcare (Figure 1). Through this network, patients' medication records, including current medications and a summary of medical records, is exchanged by an EDIFACT[1]-based communication protocol named OZIS-DWA1.0. Communication by way of this protocol is rendered operational by an intermediate system (the OZIS sever) from another major local vendor.

Each time a patient is admitted to hospital an enquiry is sent to primary healthcare. The reply is returned through the network and contains the patient's medication record(s). Data from primary healthcare is integrated into Zamicom. To create the message, two main 'drug-related' and 'disease-related' record structures are considered in Pharmacom for the period of the last 15 months. From drug-related records, 'delivered medication records' are listed into the message if they are indicated by code "C" (continuous medication) or "P" (PRN[2] medication) in front of them; all the "current medication" (coded with "*") are listed unless they have been stopped manually (active stop) in the system. Drug allergies and contraindications are also picked up from here into the message. From disease-related records, patient chronic conditions and co-morbidities such as diabetes are listed. Moreover, patient characteristics, including date of birth and gender are also included into the message.

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[1] The electronic data interchange for administration, communication and transport.

[2] A PRN medication is a drug used by a patient whenever symptoms of the disease occur.

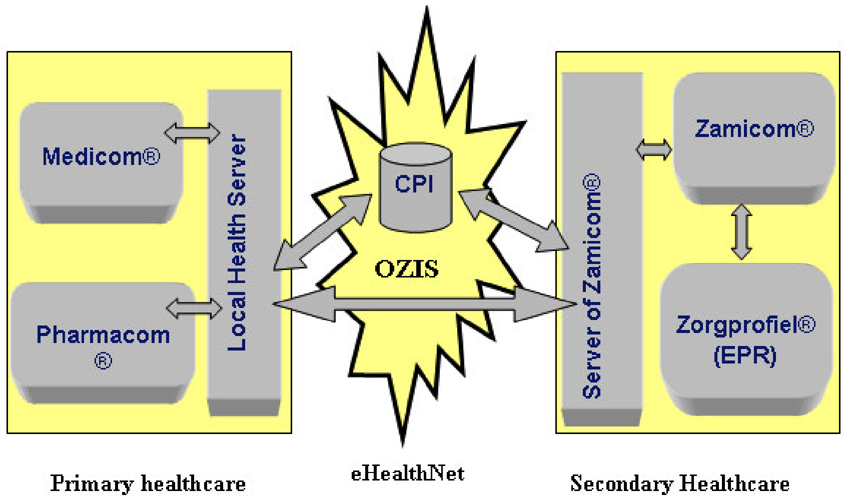

Figure 1. Schematic representation of the technical integration in TUMA.

3. Methods

In this study, building a communication network was considered as developing a "loop" within which care providers try to communicate in order to link and complement each others medication work [20, 21]. If this communication network has to be interoperable, this loop has to contain communicative *norms*[1] in its core in order to help care providers to bind together (i.e., articulate) their work and to build mutual understanding upon the exchanged information [21, 22]. The word "loop" emphasizes the end-to-end closure of the medication data communication within the network. It emphasizes that patients' medication records have to be circulated and updated by different care providers (in a timely manner) without suffering any loss or distortion. Evaluating the medication data transaction within this frame of reference helped us to consider and to evaluate the factors – either related to the system or to its users or to the implementation environment – that hamper the preservation of data integrity or the integration of different pieces of data.

[1] Here, norm means a principle of a right action binding upon the members of a group and serving to guide, control, or regulate proper and acceptable behavior (Merriam Webster Dictionary). Please also see Chapter 1 for more explanation.

Launched in 2004, TUMA went live in March 2005. We were involved in its evaluation as an external research group; this evaluation was in line with our research interest in understanding the development of local communication networks in the Dutch healthcare system [14, 19]. The evaluation took place in two stages; the first stage started in January 2005, before the project became operational. During this stage our evaluation was mostly focused on project level. The second stage started in July 2005 during which we mostly focused on work-floor (Figure 2). Almost 1 month later the project ran into unforeseen problems, which are briefly discussed in Section 4. We also had to stop data collection from work-floor and shift the evaluation focus to project level in order to find out the reasons of this halt. Almost 8 months later, in April 2006, after the problems had been dealt with, we were able return to the field and continue our data collection. The study finished in July 2006 (Figure 2).

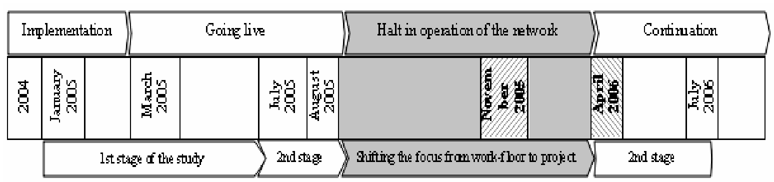

Figure 4. The timeline of the project and research in TUMA. The blocks filled with diagonal lines show the dates when the system was tested by hospital pharmacists.

Qualitative research methods were used to evaluate the attainment of data integration and saving data integrity in TUMA. We conducted interviews in both stages of the study, and in the second, we also analyzed documents and made observations. Among the care providers in the Almere region, community and hospital pharmacists played the main role in implementing and testing the TUMA network. Together with the project team, pharmacists were the main stakeholders in TUMA and thus were the focus of our interviews and observation.

The first author interviewed the project leader, two project managers, two community pharmacists, and four hospital pharmacists. In total, 10 interviews were conducted, each lasting 1.5-2 hours; four of the interviews were during the first stage and six interviews during the second. The semi-structured, in-depth interviews were one-on-one and face-to-face. The interviews were audio taped, transcribed, and coded according to Bowling [23]. They were then integrally analyzed for emerging trends based on *Grounded Theory*. Interviews conducted in the first stage of the research provided useful information about the study context, medication data communication and the information gaps prior to

TUMA, the baseline measurements. In the second stage, we asked the interviewees about the changes in their work, the improvement, and the problems; after the network was tested, we also asked their opinion about reasons for the problems in the test results. These interviews helped us to discover and to deepen our understanding of changes brought about by TUMA, to interpret the results of the network's tests, and to recognize the challenges faced in the effort to create and maintain interoperability.

To understand how community and hospital pharmacists deal with medication data, the first author observed their work for approximately 6 hours during the second stage of the project. At the primary healthcare level, the observation focused on how community pharmacy technicians entered data into information systems; at the hospital, it focused on data entry in Zamicom and data acquisition from primary healthcare. During the observations, pharmacists were asked about their experiences with the system and the reasons for commonly encountered problems. Notes were made and analyzed in the same way as the data from the interviews.

After the network was set up and tested technically, hospital pharmacists evaluated the functionality of the network as part of the implementation improvement process. The first test was done in November 2005 by requesting from one community pharmacist the medication records for 100 randomly chosen primary care patients. The results of the enquiry in Zamicom were then compared with the original data in Pharmacom. The results were evaluated and commented upon by a hospital pharmacist, the community pharmacist, and the system vendor with respect to reasons for message inconsistencies with the original data as well as other problems. After necessary interventions were carried out to improve the network performance, a second test was conducted in April 2006, again by requesting medication records for 100 randomly selected primary care patients (excluding those that had been chosen for the first test) from the same community pharmacist. As the second test was performed on the medication records from the same community pharmacist, the result of the test could reflect the effect of improvement measures. We analyzed the results of the two tests both qualitatively and quantitatively (descriptive analysis), drawing upon the comments of the parties on the test results and the pre- and post-implementation interviews with pharmacists. Four main sources of problems in the test results were defined and the problematic items of both tests were then distributed among the authors for final classification.

4. Results

First, results of the pre-implementation study are presented to depict the pitfalls and information gaps in the old medication data communication. Second, TUMA and its effect on bridging the information gaps and improving the communication are presented, focusing on the test results and their analysis. Third, important unforeseen problems and conflicts related to the articulation work and responsibility distribution between the involved parties are presented, focusing on their impact on TUMA.

4.1. INFORMATION GAPS IN THE MEDICATION DATA COMMUNICATION LOOP PRIOR TO TUMA

At the primary care level of the medication process loop, GPs were entering patient data into their information system based on "episodes"[1]. Except for a diagnosis, which was coded by ICPC[2]-2, and medication data, which was coded by ATC[3]-classification, most data entries into Medicom were made in free text format. Community pharmacists also used the same ATC-classification to code data. GPs and community pharmacists shared patients' medication records through their information systems; however, direct communication (e.g., phone calls) was also common between them. GPs and community pharmacists in The Netherlands already communicated to a certain extent, but Almere is unique with respect to the extent of communication and collaboration that exists among GPs and community pharmacists (please also see Section 2).

> "We in primary healthcare always check each other's work [on patient medication]. This is normally done both by our information system and by direct observation of the prescriptions. If we see there is something wrong in the prescriptions, we just pick up the phone and call the GP for further clarification. Every time a prescription is filled, the information system generates an automatic message that updates the records of the prescribing GP." [A community pharmacist]

Hospital pharmacists stated that, in most cases, GP referral letters did not contain medication data for hospital care providers. This created the first *information gap* in the communication loop between primary and secondary patient care. To fill this gap, patients themselves were frequently the source of

[1] For GPs, the unit of observation is called "episode" and refers to a patient with a specific medical problem over time.

2 International classification for primary care.

[3] Anatomical therapeutic chemical classification system.

their medication-related information when they arrived at the hospital. However, it was common that patients did not remember all the types of medication, or became confused by look-alike drug names. It was therefore possible for hospital care providers to fail to obtain an accurate medication history from patients. Some part of the patient's data might be missed when it was handed over or when it was transferred from paper-based forms into Zamicom. A hospital pharmacist reported the following:

> "A nurse failed to register a drug name (Methoteroxate) while she was taking the drug history from a patient, only because the drug had been used at intervals. The patient then got cystitis during his hospitalization and a physician prescribed Cotrimoxazole. When Cotrimoxazole treatment started for the patient, his condition suddenly worsened with leucopoenia and other signs of Methoteroxate toxicity. Such a dangerous condition happened because the nurse failed to take an appropriate drug history from the patient. Our information system failed to react to this drug interaction because Methoteroxate had not been registered in it." [A hospital pharmacist]

When discharged from the hospital, a patient was given prescriptions that had to be filled by a community pharmacist. In addition to this early contact between secondary and primary healthcare, additional information including diagnosis and medication was sent to primary care providers by means of a discharge letter. Community pharmacists claimed that this process usually took a long time. Moreover, in most cases, when patients contacted their GPs after discharge, the GPs were unaware of the most recent changes in the patients' medication. This delay created the second *information gap* in the medication data process loop.

> "After discharge [from the hospital], most patients frequently don't know what to do with the drugs they were using before hospitalization. They don't know whether they have to take them together with their discharge medication or to stop using them. They usually ask us because, as community pharmacists, we are supposed to be responsible for their medication safety. But we cannot help them, because we do not know the reasons for the changes." [A community pharmacist who was also project manager]

Therefore, patients were considered a link, filling the information gaps between primary and secondary healthcare levels. TUMA, as its authorities claimed, replaces this weakest link in the medication data process loop and builds an interoperable network.

4. 2. MEDICATION DATA INTEGRATION IN TUMA

Despite the fact that similar information systems were applied to both sides of the network, the project ran into trouble mainly due to software compatibility problems. The project stopped, and it took time until the necessary software patches were developed and tested successfully. As soon as software patches were considered working properly, the project started to run again. The first test was performed to evaluate the network operation before the application went live again. However, the results were surprising for project authorities; several problems were detected in the data transacted to Zamicom, and the number of these problems indicated the scale of the integration difficulties.

> "One main reason that the project fell behind in its timetable lay in the problems we had in integrating the medication data from primary care to Zamicom; it was a software functionality problem. To solve it, we consulted with people from other projects, who have already worked with the same method of data transaction. To our surprise, we learned that they only use the system to acquire data from primary care and then transfer it manually to Zamicom." [Project leader]

In total, 59 problematic items from 32 medication records were identified in the first test by comparing the data that emerged through the network with the original data in Pharmacom. These problematic items were evaluated and commented upon by one hospital pharmacist, by the community pharmacist whose records were involved, and the software vendors. We excluded two of the detected problems from our study because the community pharmacist, the hospital pharmacists, and the system vendor could not agree as to whether they should be considered communication problems. We then analyzed the results and comments for the remaining 57 items and allocated them into 11 groups. Table 1 shows that the problems were of different types, including data that did not make it through the network, discrepancies between the transferred data and its origin in Pharmacom, and the transference of inappropriate data.

Extensive measures were taken to reduce the problems: software patches were developed, coding system was improved, and patient medication records in Pharmacom were revised. In addition, it was decided that a free text form of patients' records should accompany every message through the system. After these changes were implemented, the network was supposed to work properly, so its performance was tested again by requesting medication records for 100 randomly chosen patients. This time, despite all the above-mentioned improvements, the total number of problematic items detected was 55 in 14 medication records. Table 1 shows the problematic items distribution among the different categories as well as the changes that occurred after the improvement measures.

Table 3 – Different categories and frequency of problematic items in the two tests.

Type of problematic items	Frequency in the 1st Test	Frequency in the 2nd Test
Missing items		
Currently used chronic medication did not appear in the message	7 (12.3%)	4 (7.3%)
Stopped chronic medication did not appear in the message	4 (7%)	4 (7.3%)
Administration data did not appear in the message	2 (3.5%)	0 (0%)
Potential (PRN) medication did not appear in the message	1 (1.7%)	6 (10.9%)
Temporary medication did not appear in the message	2 (3.5%)	3 (5.4%)
Medication appeared in double form (both in generic and commercial forms)	3 (5.3%)	0 (0%)
Stopped chronic medication appeared without the stop date	3 (5.3%)	13 (23.6%)
Wrongly appeared items		
Patient current or old medical condition records appeared in the wrong form	4 (7%)	0 (0%)
Non-chronic medication from past medication history appeared in the message	17 (29.8%)	10 (18.1%)
Non-medication related information appeared in the message	1 (1.7%)	10 (18.1%)
Unknown medication appeared in the message	5 (8.7%)	2 (3.6%)
Actively stopped medication in Pharmacom appeared in the message	8 (14%)	3 (5.4%)
Total	57 (100%)	55 (100%)

To determine the *sources* of the problematic items in both tests, we subsequently analyzed the interviews and the comments made by interested parties on the test results. With respect to their sources, we were able to allocate the problems detected in the two tests into four general categories: those due to coding system deficiencies; those due to software failures; those related to the faulty application of the coding system; and those related to the faulty application of software.

Problems due to *coding system deficiencies* included items that were a result of code mismatches or due to different granularity levels of the codes in the two information systems. For example, items such as bandages, syringes, and catheters were frequently registered in Pharamcom, while Zamicom had no registration code for them. When such data was received by Zamicom, it produced an error of "unknown medication", a problem that required the attention of a pharmacist. In Pharmacom, on the other hand, both types of diabetes (types I and II) were given the same code, while in Zamicom they were represented by different codes. The opposite scenario held for "intention to become pregnant" and "being pregnant". In Pharmacom, these conditions were each coded differently; in Zamicom, only one code represented both of them.

Problems due to *software failures* were considered solved by improving the current or the subsequent version of the software. Many software failures were related to problems in creating the message. For example, the program was picking up *temporary* medications from Pharmacom that did not have an end-date registered in the system but that were supposed to be stopped after 14 days (theoretical end-date). Since by the first test Pharmacom was not able to calculate and register this theoretical end-date, the message was picking up those medications even if they were supposed to have been stopped by the date the message was created. As another example, if a medication was registered once by its trade name and later by its generic name, both were incorporated in the message.

Problems due to the *faulty application of the coding system* included: applying a wrong code, a failure in coding while entering patient data into Medicom or Pharmacom, or a failure to update the coding status. In such instances, the necessary data would be missed, while unnecessary data would be appeared in the enquiry response to Zamicom. For example, in the test results, items were missing from the enquiry responses because GPs failed to code the episodes or coded them wrongly.

> "One important issue [in filling the message] is the end-date of usage for medications. This is especially important for temporary and PRN medications and cannot be done by our information system if they were not coded properly. If GPs do not code temporary medication properly, there will be no clue that that medication is to be stopped after a certain time. As a result, hospital pharmacists receive a long list of different drugs in their enquiry and will become confused as to which one is still used and which one has already been stopped." [A community pharmacist]

Finally, many problematic items in the test results could be considered a result of the *faulty application of software*. Those parts of medication data that had to do with delivering and administration were managed by community pharmacists. However, in Zamicom it was possible to enter something else in the space where a drug's name had to be registered. Hospital pharmacists experienced communication problems especially after the second test because, for instance, community pharmacy assistants used this information system's possibility inappropriately: for example, writing "the status is OK" instead of inserting the name of the medication. Another example concerned instances of pharmacy technicians failing to enter an end-date for non-current items; this led to the appearance of this medication in the enquiry response.

> "The chronic medications are labeled with code C at the beginning of their listing in the information system. However, we know that this code does not mean that a drug has to be continued forever. Some chronic medications are discontinued or switched to other ones after a while. If community pharmacists do not update the drug's status in their information system, the discontinued drugs will be presented in response to our enquiry. This is something that the community pharmacists usually forget to do." [A hospital pharmacist]

The sources of the problematic items were also analyzed *quantitatively*, and the result is shown in Table 2. The analysis demonstrated that the most common sources of problems in the first test were either related to software (35.1%) or to faulty application of software (38.6%). In the second test, the total number of the problematic items changed slightly (57 vs. 55), while the reasons for the problems shifted considerably. Problems due to software or due to coding system decreased considerably; however, the rate of the problems concerning faulty applications of the coding system (34.5% vs. 19.3%) and software (54.5% vs. 38.6%) increased tremendously.

Table 4 – Categories and frequency of the problems' sources in the first and the second tests.

Sources of problematic items	**Number of the problems in the 1st test**	**Frequency among the total problematic items (%)**	**Number of the problems in the 2nd test**	**Frequency among the total problematic items (%)**
Faulty application of the coding system	11	19.3	19	34.5
Faulty application of software	22	38.6	30	54.5
Coding system deficiency	4	7	1	1.8
Software problem	20	35.1	5	9.1
Total	57	100	55	100

Note: one hundred records were evaluated in every test and some of the records have more than one problem.

4. 3. UNFORESEEN PROBLEMS AND CONFLICTS

An important responsibility of community pharmacists in TUMA was to code the administration of drugs in their information system precisely. However, this could not be done unless GPs coded medications rightly in their information systems. Therefore, the medication coding work became a joint work and responsibility between GPs and community pharmacists. The community pharmacists in TUMA ran into trouble with respect to this coding responsibility since it was an unforeseen and unmanaged conflict between GPs and community pharmacists.

> "For example, if a GP prescribes a medication that has to be used at half an ordinary dose and does not code it properly in his information system, our system will calculate it, for example, for one and half months and after that time, the system will show that the drug is stopped by the patient. Yet, the patient has the drug at home and will use it for a further one and half months. This is something that the system cannot do automatically; it has to be done manually by GPs. However, there is a problem at the moment with respect to convincing GPs to accept this responsibility. They argue that they are not interested in doing this work, and excuse themselves for being busy." [A community pharmacist after the second test]

One responsibility of the hospital pharmacy department in TUMA is to keep the data transmission line from primary healthcare to the hospital wards operational. In order to do this, and to integrate primary with secondary healthcare data as well as the communication between the information systems in TUMA, specialist attention and manual steps are required by hospital pharmacists. As practically it was not possible to correct all old medication records in the primary healthcare, appearing problematic items were expected to persist. There was a great concern that if hospital pharmacists did not correct the problematic items in the messages, specialist physicians in the wards would not appreciate using the system. On the other hand, there was no exact idea what portion of the medication data had to be observed, checked, and improved by hospital pharmacists. And hospital pharmacists were concerned about the time and effort they were forced to spend on the process, especially as this type of contribution and the role of hospital pharmacists was not anticipated by the project team.

One ambition of the TUMA project team was to replace the patient – the weakest link in the medication data transaction loop – with ICT. Nevertheless, the contribution of patients in saving the integrity of data and in integrating medication data is valuable. We discovered at least three reasons in TUMA why this is still the case. First, some patients have to fill their prescriptions at a pharmacy other than their designated community pharmacy. Second, over-the-counter drugs (OTCs) are not registered in any information system and thus their names are requested by medical specialists. Last but not least, the adherence of patients to the medication administration plan from primary care needs to be verified. These aspects of a patient's medication history are important and can only be obtained through a patient's involvement in the medication data communication loop.

5. Discussion

The results of our study demonstrate that the technical integration of information systems is necessary but it is not enough to save data integrity and to integrate various pieces of patient data during the communication process. Other factors are important. The Almere situation was ideal for the technical integration of a healthcare information system, since there was a well-integrated communication network at the primary healthcare level and all participants use same-vendor information systems. Only one general hospital was in the region, and it also used a very similar information system and the same standards for data coding. Nevertheless, a number of communication problems arose in the course of testing the TUMA network. The persistence of the problems even after extensive technical improvements made it clear that the creation of technically integrated information systems is not a straightforward solution to achieving data integration and to preserving data integrity. Moreover, results of the second test demonstrated that while the total number of communication problems did not change in comparison to the first, most of the problems shifted toward faulty application of software and coding system. This implies that technical integration is not to blame for the problems encountered in TUMA; the work processes had to be integrated and the work routines and habits of users had to be improved if data integration and the preserving of data integrity were to be accomplished.

In many studies, the heterogeneity of information systems and standards are referred to as main impediments to building interoperable communication networks [13, 18, 24]. Our study, however, shows that social and organizational factors are also paramount. Lack of attention to how the technological artifact will affect and be affected by the organization in which it becomes embedded lies at the core of many technological failures [11]. Hanseth et al. [25] argue that practices and technologies co-develop over time and adapt to each other, creating a socio-technical network. In the mutual effect of technology and work practices, one changes the other. This means that "technology changes work practices, which in turn changes how the technology is used, which leads to changes in the technology, which induces new changes in work practices, and so on" [11]. It means that alterations in either the technical or the social realm will somehow require alterations in the other. Building an interoperable communication network through the integration of information systems, therefore, requires changes in the organization of care practices and the way people use the system. It is clear that the registering and coding of medication-related data in primary care have to be adapted to facilitate the retrieval and use of this data by a medical specialist at the hospital. In TUMA, however, we found idiosyncratic uses of the information and coding systems by GPs and community pharmacists. Although those uses were appropriate for their purposes and saved considerable time, they were considered inappropriate for hospital pharmacists, since they resulted in communication problems that required the pharmacists to pay special attention and to try to solve the problems. The second test showed that the amount of "non-medication-related information" was increased considerably. This, we think, was due to persisting inappropriate application of the information systems, which led the community pharmacist's staff to make more mistakes and which, for example, resulted in information (e.g., the status is OK) being inserted in inappropriate places. Moreover, since TUMA-required type of articulation work was not performed to integrate the work of different care providers across the network, the community pharmacy staff could not fill in all the missing data in their information system without the GPs' cooperation. For example, they inserted the missing code for chronic medications but could not enter the end-date of those medications. As a result, the numbers of "missing end-date of an old chronic medication" was increased dramatically in the second test.

Whereas most technical (e.g., software) problems seemed solvable, the use of the system implied the need to create extra checks in the socio-technical network. In the second test, despite all the improvement measures, the total number of problematic items remained almost the same, mainly because the number of problems due to non-technical reasons increased. This was an unexpected result. We believe the improvement measures after the first test could improve some of the software functionality problems and the coding system deficiencies; however, at the same time they did not change or they even added to the non-technical problems. Interesting is that data integration as a practical accomplishment in the TUMA project was only achieved by hospital pharmacists checking and improving primary care medication data. Our study therefore confirms that it is not possible to build an interoperable communication network and to fill the information gaps merely by the technical integration of information systems; the work processes of communicating care providers in the network also have to be integrated. Thus, the technical linkage is not the real problem in integration; it is that the technical linkage is implemented without the work processes being aligned and interconnected.

An increasing number of publications describe projects that integrate data from multiple information systems. However, as Cruz-Correia et al. [15] argue, one key omission in most of these publications is the mention of any type of error detection; this leaves the effect of integration processes on data quality inadequately researched. In this paper we elaborated upon the problematic items that TUMA encountered in the course of its information system integration. In contrast to many of the projects that build inter-organizational communication networks upon diverse information systems, in this study we reported on a condition of similar information and coding systems. Hence, the problems discussed in this paper are most likely to occur in many communication projects in which there are less ideal a priori conditions. Though our study involved a situation quite different from that of Ellingsen and Monteiro [13] and Monterio et al. [26], there are many similarities in the kinds of problems encountered. While some of these problems might be resolved over time (e.g., GPs become accustomed to a coding routine that is appropriate for other users), some of them (e.g., the work load of hospital pharmacists) are likely to persist or to transform into other difficulties that may compromise instead of improve patient safety [27]. This is not to say that building an interoperable communication network should not be strived for, but the socio-technical links that exist within the process of integrating information systems in healthcare must be taken into account. As a fully automated process is still far from realization in healthcare settings, human interference may be reduced or transformed, but it is still necessary in many instances of information communication processes: for instance, for the validation of exchanged data or the clarification of ambiguous information.

One important issue concerns the role and the position of patients. We saw that patients, prior to TUMA, played an important part in transferring their medication data from one level of healthcare to the other; their role was that of a messenger [28]. However, although patients were able to provide information to care providers in a timely fashion, it was known that their information was not always reliable. Studies have shown that patients get it wrong 28-38% of the time [28, 29]. Nevertheless, after the implementation of TUMA their role was still dominant in verifying and updating their medication data and thus in preventing medication errors. Patients are an integral part of the medication data communication loop and their verification role has to be considered in every project [29]. For example, in a study by van der Kam et al. [16] on medication data exchange between GPs and pharmacists, there was no difference between electronic and paper-based communication with respect to the drugs "reported only by patients". Therefore, ignoring the role of a patient in completing and updating medication data can lead to the integrity of the data being damaged. However, further studies are required to conceptualize an appropriate place for the contribution of patients in inter-organizational communication networks.

This study had several limitations. First, the study on TUMA only involved taking patient medication records from primary healthcare to the hospital.

However, it is clear from our analysis that similar problems, only on a larger scale, will be encountered when communication from the hospital to primary healthcare becomes operational. Second, the hospital pharmacist information system was an application shared with the nearby hospital in the city of Lelystad. This posed problems for the project; for example, there was resistance to carrying out the required adaptations to the system's server at Lelystad's hospital. We also observed that logging into Zamicom from the Flevo hospital was sometimes difficult and time consuming. Third, defining categories for the problem sources was a challenging issue. The problems were in many instances socio-technical, while the categories drew a line between social and technical issues. For example, the inappropriate use of a data field in Pharmacom can be considered a user problem or a software problem that does not prevent this user mistake. To cope with this challenge, we carefully defined different categories and remained with these definitions in allocating the different communication problems. Any interpretation of the test results is limited to the definition of the categories. Fourth, although the study brought up the potential sources of medication errors during the communication process, quantifying and determining their clinical importance were not of immediate relevance here.

6. Conclusion

With regard to the exchange of medication information, the safeguarding of data integrity and the integration of different pieces of medication data are crucial to create and maintain the interoperability of healthcare providers. Our study shows that technical integration is not the real problem in an interoperable communication; the problem emerges when the technical linkage is implemented without the work processes being aligned and integrated and the work routines being improved. Moreover, a thorough communication solution must address a way to combine the role of patients with that of other care providers in the communication network.

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CHAPTER 5

Inter-organizational communication networks in healthcare: centralized versus decentralized approaches

Habibollah Pirnejad, Roland Bal, Arjen P. Stoop, Marc Berg

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Abstract

Background: To afford efficient and high quality care, healthcare providers increasingly need to exchange patient data. The existence of a communication network amongst care providers will help them to exchange patient data more efficiently. Information and communication technology (ICT) has much potential to facilitate the development of such a communication network. In order to offer integrated care interoperability of healthcare organizations based upon the exchanged data is of crucial importance. However, complications around such a development are beyond technical impediments.
Objectives: To determine the challenges and complexities involved in building an Inter-organizational Communication network (IOCN) in healthcare and the appropriations in the strategies.
Case study: Interviews, literature review, and document analysis were conducted to analyze the developments that have taken place toward building a countrywide electronic patient record and its challenges in The Netherlands. Due to the interrelated nature of technical and non-technical problems, a socio-technical approach was used to analyze the data and define the challenges.
Results: Organizational and cultural changes are necessary before technical solutions can be applied. There are organizational, financial, political, and ethicolegal challenges that have to be addressed appropriately. Two different approaches, one "centralized" and the other "decentralized" have been used by Dutch healthcare providers to adopt the necessary changes and cope with these challenges.
Conclusion: The best solutions in building an IOCN have to be drawn from both the centralized and the decentralized approaches. Local communication initiatives have to be supervised and supported centrally and incentives at the organizations' interest level have to be created to encourage the stakeholder organizations to adopt the necessary changes.

1. Introduction

Present healthcare systems are identified as fragmented organizations that have many shortcomings in the ability to respond to the growing demands of the community [1]. New advances in medical knowledge promise a longer and healthier life for chronic and handicapped patients. At the same time, however, they introduce more specialty and subspecialty domains to medical practice leading to more fragmentation in healthcare systems. The trend for current healthcare delivery systems will inevitably be a migration from acute towards chronic healthcare and from centralized towards decentralized medical practice. Such a healthcare system will need more and better collaboration amongst different care providers. Future healthcare systems will therefore increasingly rely on effective communication to achieve efficient, multidisciplinary, and integrated healthcare.

Good communication is the cornerstone of integrated care practices [1-3] and may have a direct impact on patient outcomes [4-6]. The lack of good communication can produce medical errors and increase morbidity and mortality in healthcare [1, 6-9]. Information and communication technologies (ICT) can supply healthcare providers with a secure, safe, and reliable way to access different parts of patient data stored in different databases of different organizations. The creation of an Inter-Organizational Communication Network (IOCN) by information technology is seen as a promising way to afford integrated care and improve the quality in healthcare services. Fulfilling such promises, however, is dependent on the level to which information systems within an IOCN can be integrated and are able to support interoperability amongst the communicators.

Every approach to an IOCN has to address many interrelated technical and non-technical complexities at the same time. Developing such a communication network amongst different healthcare providers requires integrating different and in most cases incompatible technical infrastructures. This technical issue becomes more complicated if we consider that every provider has a special reason for building such a communication network. Nonetheless, the importance of IOCN becomes increasingly evident, and healthcare authorities in many countries, such as the Netherlands, Sweden, Canada, and the UK are investing heavily to integrate their disparate healthcare units by building communication networks through information technology [10, 11].

Up until now, only a few studies have focused on the mechanisms and challenges of integrating diverse information systems at a large scale [12, 13], and most of the studies have focused on single tools, artifacts, and protocols [14]. These studies have identified similar challenges that are encountered in the development of IOCNs, despite differences in the healthcare systems in which these are embedded [10, 11]. There is then much to learn from each other since we are now faced with the development of national and regional health information strategies in many countries.

In this paper we analyze the development of a national medication record[1] in The Netherlands [15] as a case study to illustrate the kinds of problems that are encountered and the experiences so far in trying to solve these issues. Our study contributes to understanding the challenges and complexities in building an IOCN in healthcare and the appropriations in the strategies. More specifically, we focus on the parties – general practitioners (GP), medical specialists, and pharmacists – that are responsible for patient medication safety and therefore need to exchange patient medication records. Two different approaches (centralized vs. decentralized) that have been framed amongst these parties are distinguished. The building of a national IT infrastructure for medication records communication is then sketched out. We applied qualitative methods for our study and a socio-technical approach [16] is used to analyze the data to show how the technical requirements are tied up with non-technical issues and to identify the main challenges for building an IOCN. Finally, we discuss a way to address those challenges.

2. Study context

In The Netherlands, GPs act as the gatekeepers between primary and secondary healthcare [2]. GPs have been using computers for many years in their offices, and most of the Dutch patients' medical data is stored in GP information systems. While in the past, the prototypical general medical practice was a solo practice, we now increasingly see larger and multidisciplinary primary care centers arising. Moreover, new GPs increasingly tend to work part-time and the majority of GPs are currently organized in Central GP Stations[2], enabling the use of substitutes during off times [17, 18]. Yet, the substitute GPs in many cases do not have access to patient data stored in regular GP information systems and this may increase the risk of medical error in their practice [17, 19]. These changes in GP practices increase the need for communication and data sharing amongst them.

[1] This includes patient medication data and a summary of patient medical records.

[2] The Central GP Station is the organization of GPs at the municipal or provincial levels, which can provide GPs with a substitute GP during their holidays and off times.

GPs, moreover, need to be in mutual communication with care providers at the secondary care level, especially medical specialists. As family doctors, GPs need to know what happens to their patients when they go to the hospital, especially when they must continue a therapeutic plan after hospital discharge. In addition, secondary care providers need access to the hospitalized patients' medical records, such as medication data, from primary care in order to provide quality care.

Pharmacists also need to be kept in the communication loop. According to an agreement between the Ministry of Health and the Royal Dutch Society for Pharmacies (KNMP) in October 1999, pharmacist care was incorporated into the Dutch Medical Treatment Contracts Act (WGBO) [20]. As a result, pharmacists claim responsibility for patient medication safety and want to re-check the safety of the prescribed drugs. Hence, they need access to patient medication data and diagnosis [21]. Patients have their own pharmacists that fill their prescriptions and have an overview on their medication record. Practically all pharmacies use a pharmacist information system, which contains patient-orientated medication files both for administrative purposes and to prevent unsafe combinations of drugs. However, during nights, weekends, and holidays patients have to go to shift pharmacies, where pharmacists do not normally have access to their medication records [22].

Because medication data is not shared amongst these professionals, money is wasted and many lives are potentially put in danger. A recent study from WINAP (the scientific institute of pharmacists in the Netherlands) estimated that 90,000 hospitalizations occur each year as a result of "avoidable medication errors". This represents an annual cost of 300 million Euros [23]. The term "avoidable medication errors" refers to the fact that at least some of these errors could be avoided if the patients' medication record had been available to healthcare providers at the right time and the right place.

For many reasons, other stakeholders may also need to be in the medication data communication loop, or may have an indirect impact on building medication records communication networks (e.g. government organizations, and insurers). In this study, however, we decided to focus on the main parties from a patient safety perspective: GPs, pharmacists, and specialist physicians. We considered other parties wherever their roles converged with these parties' roles.

3. Case study

In this case study we focus on The Netherlands as a country facing the complex development of a national communication network. The developments have been followed since 2004. In order to collect baseline information about network development amongst the parties, the problems they encountered, and the actions they have taken so far, we reviewed the literature related to communication in the Dutch healthcare system, including publications in international or national scientific and professional journals until November 2006. Reports and documents published by the stakeholder organizations such as NICTIZ (National IT Institute for the Care Sector of the Netherlands) were also analyzed. In order to deepen our insight into the mechanisms and dynamics of network development processes, we also conducted 10 interviews with senior managers of regional communication projects, IT experts, experts in the Dutch healthcare system, GPs, pharmacists and specialist physicians involved in medication data communication projects. The in-depth interviews were semi-structured, one by one, and face-to-face, with each one lasting approximately 1.5 hours. Interviews were integrally transcribed and analyzed for emerging trends. The gathered data was used to analyze the ways in which medication data communication is framed in the Dutch healthcare system.

In this study, we applied a socio-technical approach to analyze emergent complexities in building IOCNs, and to define the challenges for such a development. Socio-technical approaches have frequently been used to explain the interrelationships between social and technical issues in the development of information systems, focusing on the 'fit' between the organization of working practices and information technologies [24-27]. Studies in the socio-technical tradition have particularly been powerful in understanding the reasons behind the poor acceptability, uptake, and performance of many ICT interventions [16], but have also focused on how information technologies are appropriated in healthcare practices [28]. Adoption of this perspective allows us to think about a broad class of phenomena that are crucial to uncovering the mechanisms that lead to the development of an information system, its appropriations once it is used in healthcare practice and its integration mechanisms with other information systems [24].

4. Medication records communication amongst the Dutch healthcare providers

Healthcare inter-organizational communication has proved to be problematic in the Netherlands. At the primary care level, studies show that though 80% of GPs use an electronic prescription system, only 10-35% of prescriptions are transmitted to community pharmacists electronically and less than 5% of GPs get an up-to-date summary of all medication/aids supplied from the local pharmacy [19]. In the communication between primary and secondary care, the referral letters from GPs do not usually contain the necessary information for specialist physicians and hospital pharmacists and less than 1% of the specialists have electronic insight into medication supplied by community pharmacies [19, 29]. A hospital pharmacist describes the situation as follows:

> "Patients are normally asked about their medication history at the hospital. The information is then registered using paper-based forms and is sent to us [at the pharmacy department] to be entered into our information system. Our observational role and our information system's work are based on this information that sometimes is not reliable at all." [A hospital pharmacist, local project manger]

The quality of communication to the GP is sub-optimal; the discharge letters take a long time to be received by primary care providers [30]. In general, less than 5% of the prescriptions generated by specialists are received electronically by community pharmacies [19]. After a patient is discharged from the hospital, his GP and community pharmacist often have no idea about the changes in their patients' medication. Despite obvious needs for communication there is no reliable way for primary and secondary care providers to communicate patient data. A community pharmacist explains the situation as follows:

> "When a patient comes with a discharge prescription in his hand, we have no idea why the patient has to receive those drugs after discharge from the hospital. We do not know why his medications were changed and whether the specialist physician had considered the patient's medical records from primary care. Therefore, we cannot properly check the prescription's safety and offer the necessary advice for patients." [A community pharmacist, local project manger]

5. Inter-organizational communication and its approaches

Two approaches can be distinguished in developing a communication network amongst Dutch GPs, specialist physicians, and pharmacists for medication records exchange. The first "decentralized approach" is a bottom-up development, starting from *micro level changes* amongst the parties that want to build communication networks (Table 1). This approach consists of scattered projects based on local IT procurement and the minimal infrastructures to support local communication initiatives. The development process is not steered by a centrally designed plan or a detailed strategy. Rather it follows a pragmatic approach with the aim of trying to address the parities' *immediate needs,* albeit in a loosely structured manner. The development proceeds by small incremental advances which are the products of a dynamic negotiation amongst the parties that have horizontal relationships with each other in the development process. In effect, the process of network building is manageable to local circumstances and its speed is congruent to the creation of shared interests [31]. One pitfall of this approach is that it involves a long-term process. Moreover, since these networks develop regionally, it is a challenge to manage any *macro-level changes* (e.g. policy making, legislation) which are necessary for a nationwide integration.

The second approach is in many aspects the converse of the decentralized approach; hence it can be called a “centralized approach”. It consists of a single large-scale project that is governed by a *central party*, determined by the government, and assigns other stakeholder parties to join the development process. The central party has the power to arrange the required *macro level changes* for networking, such as providing the necessary infrastructure, supporting IT policy and law and so forth. The course and the goals are predetermined and there is a strategy that offers the best solutions for the potential development problems. The implementation is top-down with a big-bang introduction and the deadlines in this approach ensure that the development will progress at a desired pace (Table 1). However, the speed of the process challenges the ability of the development strategy to address unexpected problems and changes. Moreover, since this approach is applied in a top-down fashion, the management of any necessary micro level changes represents a formidable challenge.

Table 5. Summary of differences between the centralized and decentralized approaches

	Centralized Approach	**Decentralized Approach**
Consisted of	One large project	Small scattered projects
Involvement of parties	By central assignment	By negotiation
Start	From a macro level	From a micro level
Strategy	One comprehensive solution for all problems of the end-users	Pragmatic approach to solve immediate needs of the end-users
Governing	Power is localized in a central party	Power-sharing amongst parties through negotiation
Implementation	Top-down	Bottom-up
Change management	Macro level > Micro level	Micro level > Macro level
Timing	Big bang	Small incremental advances

In The Netherlands, the decentralized approach has been gradually developed throughout the years, starting from the regional clusters of GPs and community pharmacists that use information systems from the same vendor. By sharing the same server, these clusters usually built [application specific] networks through which they could share patients' medication records [17]. Since 1998, the domain of this networking process has expanded beyond the clusters by means of a lightweight infrastructure; a communication protocol named OZIS[1]. Gradually, OZIS has become the central notion to this approach, allowing the primary care providers, especially Dutch community pharmacists, to communicate patient medication records across their different information systems [22]. During the past few years, some of these regional projects have tried to connect their local primary care network to secondary healthcare, using OZIS based messaging mechanisms. These initiations, which are limited to communicating patients' medication records between primary and secondary care, have booked considerable results in some cases, even though they are still challenged by many issues (e.g., coding) as described below [32].

The centralized approach also has a long history in The Netherlands, but gained new impetus in January 2002, when the Dutch government established NICTIZ[2] to facilitate communication amongst the healthcare stakeholders. NICTIZ is a publicly sponsored organization, trying to bring together different stakeholders in the Dutch healthcare system, and provide a nationwide vision for building a national Electronic Patient Record (EPR) that can fully represent all relevant patient data for every healthcare stakeholder at any time and at any place [19]. One of the main tasks of NICTIZ is to support the construction of a communication network. As a short-term goal, NICTIZ has focused on exchanging medication records, which is considered as a common interest amongst the participants. The early plan was to have patient medication records available in one region in 2004 and nation-wide in 2006. This plan seemed to be realistic at the time NICTIZ succeeded in taking good steps in defining standards and providing some necessary technical infrastructure for an inter-organizational communication. However, it later became clear that the plan was too ambitious to be realized by those deadlines. NICTIZ has since developed a national healthcare information hub, known as LSP in Dutch, which makes information exchange of different care providers feasible. No patient information will be stored in the hub, except a record of which information on which patient is kept by which healthcare practitioner as well as a log of who has accessed what information. In principle, GPs could read a professional summary of a patient's record by using their care unique identification card, while physicians and

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[1] OZIS (the 'open care information standard') are EDIFACT based protocols for data transaction in primary healthcare or between primary and secondary healthcare.

[2] 'Nationaal ICT Instituut in de Zorg'.

pharmacists could read the medication overview of patients. The hub became operational and could be tested only recently. In the near future, by connecting different care providers [in one region] to this hub the real implementation phase toward building an IOCN will start. In order to connect to the hub different care providers will have to upgrade their information system in order to comply with the qualifications determined by NICTIZ, Qualified Healthcare Information System [33].

6. The current Dutch healthcare information infrastructure

The purpose of building an IOCN is to make different care providers work cooperatively on the same set of data by integrating the fragmented and distributed pieces of patient data. For such a purpose, information systems must be able to exchange information and process the exchanged information, or in other words the information systems must be 'interoperable'. To accomplish interoperable data transaction, both the sender and the receiver systems must use a standard format, content, vocabulary as well as delivery mode, i.e. "syntactic interoperability" [3, 34]. Moreover, the underlying Reference Information Model (RIM) of the information systems must be able to support the information transaction and its integration [35]. This means that the RIM of information systems must include the concepts, attributes, and relationships needed to describe aspects of care providers' work, i.e. "semantic interoperability". Therefore, interoperability is at centre stage of every 'true communication network' and to maintain such functionality, there are two main technical concerns: standards and RIM.

Building an interoperable IOCN requires an appropriate infrastructure, standard and RIM. However, solving the problems with old infrastructure or adopting a new information infrastructure is not merely a technical but rather a socio-technical issue. The work practices and infrastructure technologies have co-developed over time within the healthcare stakeholder organizations. They are mutually adapted to each other to form a socio-technical network, making it difficult to change one of them without changing the other [36]. Four main categories of challenges for changing infrastructures are presented below using a socio-technical perspective. Wherever possible, we analyzed how the two different Dutch approaches managed to meet these challenges.

6. 1. POLITICAL COMMITMENT

Many changes, both at the micro and macro levels, are needed to set up an IOCN. At the macro level, managers are required to take appropriate strategies and policies needed to cope with significant changes in infrastructure technologies. At the micro level, on the other hand, end-users are required to adopt the necessary changes, for example in their routines and working behaviors. As argued, the decentralized approach basically grows upon the micro level changes and the horizontal relationships between the participant organizations in order to build *political commitment* amongst each and every participant organization to cope with changes. On the down side, this approach has difficulty dealing with macro level changes due to power limitations. In contrast, the centralized approach can more easily deal with macro level changes; the challenge in that approach is to create commitment amongst all stakeholders.

In general, the RIMs of the current Dutch healthcare information systems lack the ability to support inter-organizational communication. Changing the RIM and adopting a new technology despite its feasibility is far from being merely a technical fix. History shows that many social issues have so far been involved. For instance, the Reference Information Model (RIM) of the present Dutch GPISs (WCIA[1]-RIM introduced in 1996 and upgraded in 2000 and 2001) has been considered a major impediment for communicating patient data, as this RIM lacks a data model that supports information exchange. Despite the technical feasibility of upgrading the systems, the problem with communication through GPISs has not been improved so far [17]. One reason for this was concern by vendors about privacy and data safety. Another reason was that data exchange beyond their own systems was seen as a risk to their competitive position on the ICT market.

The history of the decentralized approach, on the other hand, shows that its success in solving communication problems has mainly been due to its success in gaining the participants' commitment to cope with the required changes. The mid 1990s was the period when Dutch pharmacists started to see the lack of communicating patient data amongst themselves as a major constraint to fulfill one of their important claims, namely playing an active role in patient safety [22]. In 1995 the Royal Dutch Society for Pharmacies (KNMP) negotiated with the information system vendors to solve the communication problem amongst local pharmacists. While this led to the development of OZIS, vendors remained reluctant to change their information systems to support this communication standard, since their strategy was to create local networks of same-vendor systems. The pharmacists' decision and commitment to change the situation, however, made it possible for the Dutch government to invest money in improving the pharmaceutical situation in the Netherlands in 1999. The KNMP then used this financial aid to persuade the vendors to rebuild the RIM of the

[1] WCIA stands for Workgroup of Coordination Information Automation.

early Pharmacist Information System based on OZIS, in 2000, thus enabling data exchange between systems of different vendors [22].

In changing the standards, similar political dynamics are also in effect. Though selecting and using appropriate standards is mainly a centralized and a top-down process, its successful implementation has very much to do with users' behaviors and coding routines at the micro level. In the Dutch healthcare system, standardization has never been a solid process. GPs use the International Classification for Primary Care (ICPC) and ATC[1]-classification to register patient data in their information systems. This registration, however, mainly includes the diagnosis and medications, yet the majority of patient data is stored in the form of free text. Recent research revealed that Dutch GPs fail to register contraindication, intolerance and the discontinuation of treatment in their information systems in 22%, 15%, and 45% of the cases respectively [37]. Besides, the routine used in applying diagnostic codes varies amongst GPs and studies have shown that one code may not mean the same for different general practitioners [38]. The same problem exists with the secondary care providers. At the secondary healthcare level, the International Classification of Diseases (ICD-9-CM or ICD-10) is applied mainly for discharge purposes. It has been argued that the quality of this coding is not sufficient and studies have shown that healthcare providers at hospitals frequently code patient diagnosis inaccurately or do not code at all [39]. These studies denote the necessary micro level changes that have to be fulfilled in order to improve coding patient data. Without these changes, serious damage to communication and interoperability has to be expected.

Regarding data exchanging standards, EDIFACT[2] is widely adopted in The Netherlands for data exchange amongst healthcare organizations. However, the problem with EDIFACT and the standard protocols built on it, such as OZIS, lies mainly in integrating the transferred data within the receiving systems. Most often, the sender and receiver need to apply a tailor-made software program that will be dedicated to mapping their two types of datasets. Different standards and standardization routines amongst healthcare stakeholders, as discussed above, and the problems with the RIMs of the information systems make the data mapping and translation of message transacted by OZIS protocol in the decentralized approach a problematic process. In most cases semiautomatic steps and human intervention have to be applied to match the transacted data [32]. This requires a laborious work of reviewing already registered data by different parties. Moreover, the coding routines of care providers have to be improved upon. These are all changes that can be coped better in the

[1] Anatomical Therapeutic Chemical Classification System.

[2] The Electronic Data Interchange For Administration, Communication and Transport.

decentralized approach. In fact, the community pharmacists in some projects already started to review their databases and negotiate with other parties to improve their coding routine.

In contrast, NICTIZ is following a centralized approach and adopting HL7-V3[1], hoping to solve many of the problems with the RIMs and inconsistencies in data registration standards. Although HL7-V3 can transact data regardless of the standards used to register data, its ability to accomplish a meaningful data transfer is dependent on the degree to which care providers code their data completely and correctly. Therefore, even if NICTIZ succeeds in adopting HL7-V3, its success in building an interoperable communication network will depend on gaining the commitment of the users and parties to adopt the required micro level changes known to be hard and labor-intensive. Moreover, many of the micro level changes, such as end user adaptation and adopting new routines, are likely to be problematic in the top-down centralized approach. Since stakeholders in the decentralized approach are committed to one another, gaining their commitment to adopt the changes is more feasible compared to the centralized approach.

6. 2. FINANCIAL CHALLENGES AND INTERESTS ALIGNMENT

The cost of transition from one IT configuration to another is another important issue to consider when building an IOCN. Distribution of the costs is paramount; what is the underlying 'business model' and who will pay for what? The financial burden of building a communication network is potentially a big impediment. It becomes even more important if we consider that most Dutch healthcare organizations currently spend less than 2% of their revenues on IT. Moreover, the costs not only play a role in building IOCNs, but also in doing the works that are needed to register and code data. For example, in a study on a referral system between primary and secondary care in the Netherlands, GPs insisted on receiving financial compensation for the extra work that they were doing [40]. As mentioned above, concerns about the competitive position of vendors are also important here.

The recent Dutch IT history demonstrates that financial aids and subsidies have always been a good promoter of IT projects [22, 41]. Two decades ago, in the early introduction of computers to primary care, the Dutch government paid 100% of the expenses of computerization to GPs. The information model for this computerization was the "Groene Kaart" (Green Card): a paper-based chart that most GPs were using for data registration. When this information model was

[1] The Health Level Seven Version 3 is an international standard for storing and sharing health information.

changed from “Green Card” to “WCIA”, an accredited system, in 1990; 60% of all costs were subsidized [41, 42]. However, in the complex and interrelated process of changing information infrastructures for communication purposes, central funding will not be able to cover all local IT spending. Although some expenses will have to be incurred by individual parties, other expenses will have to be shared by all parties. These expenses do not deliver clear benefits to the individual parties and therefore are hard to distribute. Moreover, some more expenses may be incurred by organizations as a result of new regulations, such as losing their market. Many of these expenses appear gradually and lately during the course of implementation. Understandably, organizations may be reluctant to invest if some of the costs will be covered centrally. This lack of certainty in the central approach may lead to a larger IT gap between ‘cash rich’ and ‘cash poor’ organizations [43].

The history of the decentralized approach shows that many of the late expenses can be negotiated among the organizations. One of the major impediments in upgrading the pharmacist information systems was the resistance by the systems’ vendors. There were [and still are] three main vendors for pharmacist information systems in the market. They saw opening up the information systems as a threat to their interests, saving their clients [22]. The problem was solved only when KNMP guaranteed the vendors’ interests with the money that had been received from the Dutch government.

6. 3. ORGANIZATIONAL CHALLENGES

Many organizational changes are required in setting up an IOCN. Changing information infrastructure then will inevitably require the work processes of the communicators at different organizations to align with each other. This means that working practices will be affected in all participant organizations. Such changes can create tension and increase resistance among the staff to the implementation if they are not approached properly [43]. Organizational changes, therefore, have to be expected and managed at both inter-organizational and intra-organizational levels. A number of vital questions need to be addressed here. For example, when does a new organizational role, such as a new responsibility, come into effect? When is an organizational role no longer effective? Where do responsibilities of healthcare providers from different organizations, such as a GP and a specialist, overlap or interfere? And when should tasks be delegated or redistributed between organizations or care providers? Good inter-organizational relationships are key for governing these changes. For example, in studying communication networks between pharmacists, we found that those regions that had a long history of cooperation on other issues were much quicker to accept this new challenge than regions where such inter-organizational networks did not already exist [22].

These changes need to be considered and addressed carefully. Every stakeholder in fact sees the process of communication from its own standpoint and this may challenge the building of an IOCN. For example, the role of pharmacists in the process of medication records communication is challenged by doctors, leading to a resistance to share information about diagnoses. Since many of these changes are found at the micro level and they come up gradually during the implementation, they are rarely considered and may even be ignored in the centralized approach. Moreover, the participant organizations in the centralized approach usually do not represent a homogenous society of end-users. For example, only one organization represents all specialist physicians. This introduces the possibility that the interests of some end-users will be ignored. The organizational changes involved with the new IT configuration, and the fact that many stakeholder organizations lack the knowledge and strategies to cope with these changes ensures that they will move very carefully and slowly. Effectively, then, they will hinder the necessary changes. Since The Netherlands is country where policymaking in health care is seen as a process of consensus making, and since many parties are involved in setting up the Dutch national EPR [19], there is little chance that extensive progress will be made fast.

6. 4. ETHICOLEGAL CHALLENGE

The role of patients in building IOCN goes beyond that of an ordinary stakeholder and their attitudes towards sharing their data with healthcare stakeholders are very important and must be considered carefully. According to the Dutch Medical Treatment Contracts Act (WGBO), in many situations patients must be asked permission for their information to be made available to care providers and health insurers. However, even amongst different groups of patients, attitudes toward sharing data with other healthcare providers and stakeholders differ. In this regard, it is possible to distinguish different categories of patients, such as patients suffering from chronic diseases, who benefit more from data sharing and do not consider it as any important threat to their privacy [44]. Considering that patients' records serves not only as a depository for medical data but also assists in quality assurance, follow-up patient claims, and legal judgments [45], the greater focus on patient rights the visibility and accountability of patients' records.

In the centralized approach, ethicolegal impediments can be a big challenge when building an IOCN if they are not addressed appropriately. At the micro level, patient expectations about sharing their data with healthcare stakeholders must carefully be considered [46]. This consideration should focus on finding the best way to protect patient privacy rights, while letting patients benefit from advantages of healthcare inter-organizational communication [46]. On the other hand, at the macro level, legislation has to be passed in order to protect patients' rights. The current strategy of NICTIZ is to implement a so-called 'unique care professionals identification' pass, that enables both the prior authorization and control of healthcare professional to access and use the patient electronic records.

Besides a clear focus on the different interests of parties involved in centralized approach, there is also a need to establish optimal balances between the various demands placed on such systems. Since these demands may conflict with each other – e.g., creating full authorization processes for doctors looking at patient data might conflict with the time pressure in patient care work – trade-offs are inevitable. For example, in a study on the use of the 'unique care professionals identification' pass, we found that medical specialists often leave their card in the computer to avoid having to login and logout every time they need to access the system [47]. Although some of those problems might wither away when more technically sophisticated identification procedures are introduced, examples like these serve to illustrate that trade-offs are necessary. For example, it might be better to improve login and logout procedures rather than focus on authorization.

Moreover, our research shows that data privacy has never been a major concern and challenge for the decentralized approach. Whenever it is seen as problem, it is solved very pragmatically for example by positioning a notice in the waiting rooms of community pharmacists and GP offices that declares patient data could be shared. Since local projects have fairly been closed for outsiders, patients' representation is totally missing from these developments. Therefore, contrary to the centralized approach, patients' rights and privacy are not easily recognized and considered in local communication developments.

7. Discussion

The development of a nationwide communication network amongst healthcare stakeholders has been recognized as an essential strategy in many healthcare system reforms. The way to approach such a configuration, adopt the changes, and cope with its challenges, however, remains as yet an underdeveloped topic in the literature. The Netherlands is amongst the pioneers in the development of a nationwide communication network in healthcare. As we have seen for the Dutch case, there are two different approaches for this purpose, each of which faces considerable challenges to the integration of heterogeneous information systems.

Development of a true communication network requires changes to the information infrastructure of participating organizations. Since there is no single factor at play in all the changes in this field, the development process should never be considered as a matter of investing in technical factor alone (e.g., changing standards). Rather, the development has to be viewed as the integration of the [medication related] activities seen on the "work floor" of the participant organizations. There are cultural, financial, technical, political, ethical, and organizational differences that all affect the process of change adoption by these organizations. Although some of these factors can be considered beforehand, many others are hard to recognize in advance, including the consequences at the micro level. Moreover, the magnitude of differences must be multiplied by the size of the project; a larger project will therefore have to deal with greater diversity and unpredictability than a smaller project. Required changes that are not managed properly will impede the development process.

The efforts and strategies should be implemented at multiple levels to cope with micro level and macro level changes. The best solutions have to be drawn from both centralized and decentralized approaches. Such a multi-leveled approach can show how the development process has to provide the participant organizations with a solution for their immediate needs rather than a perfect solution for future needs. Instead of a top-down implementation of large-scale changes, communication initiatives based on local IT procurements can be supervised and supported centrally in order to facilitate the necessary changes that extend beyond the ability and scope of local projects (e.g., necessary legislation). Moreover, the development process in one way or another has to address the common incentives of participant organizations. Considering the nature of the challenges, different incentives can be found for the different parties, varying from financial aids to political gains, reputation, qualitative care and confidentiality assurance. On example of a financial aid would be a start-up subsidy for stakeholders expecting to bear substantial front-end expenses, in line with the understanding that a financial relationship will have to be structurally embedded. In the centralized approach, as argued, the governing party sets the goals and the course. The speed of the process in effect does not leave enough time for the parties' interplay to find the most satisfactory path through their joint incentives, and this likely mean a continuous postponement of deadlines. The decentralized approach, on the other hand, starts from the moment where the parties set out their strategies according to their joint incentives. Since at that moment the different parties have strong incentives (financial, reputation, etc) in building an IOCN, they will move to cooperate with each other and are motivated to adopt the necessary changes. The important point is to let the parties negotiate with one another to seek out a way that can address their joint interests. In a study of a local communication project between primary and secondary healthcare levels, the project leader explained how an organizational challenge in their project was met by addressing a common interest:

> "The hospital pharmacist information system in our project is a shared system with another hospital in the nearby city. The server of the information system is

> located in that hospital. During the first six months of our project it was really hard to convince the medical informatics department of that hospital to cooperate with us. It was hard even to convince them to let us put a CD in the server of the information system. … However, as soon as they started to do a similar project and build their communication network between primary and secondary care, they realized that they could benefit from our project and now they are cooperating with us very well."

The benefits of a centralized approach are potentially much greater than those of a decentralized approach. However, the realization of those benefits depends on the initiation and operation of the communication network. NICTIZ has considered "exchanging patient medication records" as a common interest amongst all parties that can facilitate the development process. However, for some parties, such as medical specialists, there is as yet no short-term gain and incentive; it would only be more registration work for them. Since they are not yet convinced that the current paper-based medication management systems are incomplete and obsolete, it has been difficult to get them on board. In stark contrast, Dutch pharmacies, as we have seen, are increasingly joining OZIS for communication purposes [22]. For them, joining OZIS is a welcome support for their professional prestige, which is being battered by ongoing media reports about excessive incomes, and a lack of relevance in the era of IT supported, integrated health care [22].

8. Conclusion

We have seen that important organizational and cultural changes are to be expected when setting up an IOCN in healthcare. We argue that pushing forward "true IOCN" in a situation where there is no sufficient political determination and a commitment to adopt the changes is bound to fail. We argue that significant changes will only emerge by means of significant changes at the level of "system incentives". We believe that IT is fundamental in integrating different healthcare organizations and generating high quality and low cost healthcare. However, the best solution has to be sought in combination of the centralized and the decentralized approaches. Local communication initiatives have to be supervised and supported; incentives at the organizations' interest level have to be created to encourage the stakeholder organizations to adopt the necessary changes.

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GENERAL DISCUSSION

Discussion

The study in this thesis began by recognizing the importance of communication in healthcare and its role in reducing errors in medical practice. Current healthcare systems have long been known to suffer from deficiencies in communication. The trend, however, has been toward a progressive need for an efficient system to disseminate information. ICT has been a promising one, especially on the basis of its success in industry. Nevertheless, its adoption by healthcare systems has been problematic. To date, a large number of unintended negative effects on healthcare processes have been reported that jeopardize the potentiality of ICT to improve healthcare communication and patient safety [1-3]. In this thesis, we focused on medication data communication in healthcare, both at intra- and inter-organizational levels. We examined the dynamics between the medication process and information technology, which lead to these adverse effects. We looked at how ICT might be applied to improve medication data communication without jeopardizing patient safety. Five sub-questions were defined, each of which was discussed within a separate chapter. In this final chapter, the significant findings are presented and a discussion is built upon them in order to answer the main research question.

We began with a literature review [4], in which we critically analyzed a number of studies concerning intra-organizational communication, which had been published in diverse scientific disciplines. This review revealed that in most cases information technology influences healthcare communication by shifting the mode of communication activities from synchronous to asynchronous. Apart from improving communication, such a shift may have counterproductive effects on mutual intelligibility between communicators. Moreover, we realized that the way in which *successful* communication is conceptualized imposes restrictions on the design and implementation of information systems. Considering successful communication to be a thorough exchange of data between information systems has many advantages for developing standards – for data registration and exchange – and for designing Reference Models of information systems. However, this conceptualization prevents conventional standards from covering all semantic aspects of healthcare communication (i.e. leaves semantic gaps). The collaborative nature of healthcare work often requires healthcare workers to build interoperability upon the exchanged information: that is, they have to fill the semantic gaps in order to communicate successfully. Because of this, rigorous standardizations based on conventional methods can result in care providers needing to carry out more synchronous, informal interactions in order to resolve the ambiguities and complexities that appear in the information exchanged through IT systems.

We argued that in an alternative approach, successful communication can be defined as building interoperability between healthcare communicators. Thus, in order for an information technology to enhance healthcare communication and patient safety, it has to improve this interoperability. Conversely, if a system hampers interoperability, it will cause healthcare workers to make mistakes in their practice. This alternative approach does not attempt to close the *communication loop* only between information systems: It considers communicators to be an integral part of the loop. Closing the loop then requires that the domain of standardization is extended to involve communicative activities in order to include those variables in healthcare communication space that produce interoperability problems. This means that as well as conventional approaches to standardize the registration and exchange of data, standardization approaches are also necessary that can *reduce the diversity* in those aspects of the communication environment that produce complexity in the organizational, cognitive, and social dimensions of healthcare communication. We contended that for an optimal use of ICT to improve healthcare communication, a multi-dimensional approach is required that addresses at least three dimensions: 1) controlling the effect of social context, 2) improving the information processing skills of healthcare personnel, and, most importantly 3) standardizing care processes.

With this model in mind, we evaluated the impact of a CPOE system on nurse-physician communication in the internal medicine wards of a large academic medical center [5]. At the time of our qualitative research, the system had been implemented successfully for almost three years and was being used by trained physicians. However, prior adjustments to the medication process, such as those mentioned in Chapter 1, had not been performed. Triangulating a pre- and post implementation survey with the qualitative data showed that the system was mainly targeted at the prescription phase and was able to improve syntactic interoperability between nurses and physicians. However, it simultaneously introduced problems, mainly in the administration and monitoring phases. The evaluation revealed interoperability obstacles throughout the medication process, which caused disruptions in the medication workflow and forced nurses and physicians to compensate by devising and applying informal ways of communication and collaboration – workarounds. Therefore, although the system had benefited patient safety, since it improved syntactic aspects of medication order communication, it also posed considerable risk for nurses and physicians to make mistakes in their practice by fostering informal practices and communication processes.

A further analysis was performed by applying the conceptual framework and comparing the CPOE system to the former paper-based system. The evaluation showed that the CPOE system improved certain non-supportive features of the paper-based system but could not replace its supportive features [6]. The main reason for many of the CPOE interoperability problems was that the highly collaborative nature of the medication work had not been taken into account in the system's design. Thus, appropriate mechanisms were not built into the system so as to integrate the work of physicians into that of nurses and vice versa.

Additional in depth analysis showed that the system impaired *feedback* and *synchronization* mechanisms between nurses and physicians. Many years of working with the paper-based system had allowed appropriate communicative mechanisms to be developed in order to articulate different segments of work performed by different healthcare providers into a smooth medication process. Introducing an information system into a care process without preliminary adjustments such as those discussed in Chapter 1 can disrupt previously established communicative mechanisms. The disrupted mechanisms loosen the links and the integration between different areas of work. In Chapter 3, we suggested technical fixes to the CPOE system that can improve communicative mechanisms and repair nurse-physician interoperability. However, once the system is implemented, repairing the impaired mechanisms, improving interoperability, and rebuilding the disrupted work process are not simply a matter of technical adjustments. The workflow needs to be modified as well if the interoperability of care providers within the developed socio-technical system is to be improved [7, 8].

Moreover, we saw that the distribution of responsibilities and the task boundaries that had been established between nurses and physicians in the paper-based system became blurred after the CPOE system was implemented [5, 9]. These unexpected changes within the poorly managed implementation environment required greater efforts on the part of nurses and physicians to carry out successful medication work. They had to configure a new structure for the medication work, and to renegotiate and redistribute the new forms of tasks and responsibilities. In our case, this new work configuration was developed gradually and was the result of three years of interaction between care providers and the system. Because the system, like numerous other commercial systems, did not have that level of flexibility to accommodate necessary adjustments in its design, the work process had to suffer increasingly.

The new work configuration also took a localized form. As a result, in different wards we found various workarounds, all of which were designed to address more or less the same problems and which led to more or less differing versions of the new configuration. Although workarounds were able to resolve many of the problems in the medication workflow, they also resulted in instability, a heavier workload and cognitive load for care providers, and a more significant risk for patient safety. Previous studies had already suggested that workarounds can obscure the counterproductive effects of a CPOE system [3]. Our findings in this study, however, indicate that workarounds can also be the source of medication errors. Given that workarounds play a major role in successful IT adoption [10], our findings challenge the notion that the implementation strategy itself is the main source of a CPOE system's unintended negative consequences [11].

We propose that whenever an information system is to be applied for a highly collaborative process, especially if the system only partially covers the process, the capability of the system in supporting the feedback and synchronization mechanisms should be carefully evaluated beforehand. In predicting synchronization and feedback problems, the interoperability has to be strengthened by simultaneous implementation of other information systems (e.g., electronic cardex system) or communication channels (e.g., an efficient telephone system) [4]. Once a system is implemented and used, applying other information system(s) to reinforce those aspects of the process that remained unsupported will not be a *comprehensive* solution to maintain interoperability. In our study, for example, it is not expected that implementing an automated bar coding and/or electronic cardex system to support the medication distribution and administration phases will resolve all the problems. This is because within the socio-technical environment, the medication process and the CPOE system are changed as a result of continuous interactions between the care providers and the system. Thus, neither the system nor the process is the same as it was before the implementation. This alteration challenges the effectiveness of the underlying assumption in the design and implementation of IT systems. After the implementation, therefore, the subsequent process has to be monitored mindfully and a workable solution needs to combine: 1) adjustments to the care process in order to compensate for communication problems, 2) adjustments to the ways the system has been used with regard to patient safety and communication concerns, and 3) accommodation of the necessary changes to the system itself.

In Chapter 4, we evaluated a regional project whose aim was to build an interoperable network for the communication of medication information between primary and secondary healthcare through information systems [12]. The intention was to build a closed communication loop between care providers. An ideal prior technical condition existed in terms of applying similar information systems and the same standards throughout the communication network. The primary assumption of the project's stakeholders was that a smooth and interoperable information exchange would occur because all the technical fixes were in place. Therefore, they did not consider it important to define a strategy to integrate the medication work of care providers in the loop, nor did they investigate whether to perform the necessary organizational changes required to close the loop. Hence, they did not train the system users in, for example, how to use information systems to properly serve communication within the loop.

We examined the network's ability to maintain data integrity and to integrate different pieces of medication information and discovered a number of communication problems. Analysis of the tests showed that many of the problems were due to faulty application of either the software or the coding system. These problems persisted even after extensive technical interventions. A subsequent analysis of the qualitative data showed that many of the problems were because the medication work of care providers across the network was not aligned and integrated. Moreover, in participant organizations, we found workarounds that were inappropriate for the network purposes, and which resulted in unexpected additional workloads for care providers, along with the unforeseen problems that challenged closing the loop. They prevented the network from functioning successfully and hindered the interoperability of care providers with regard to the exchange of medication information within the network. As a result patient safety was in jeopardy. Throughout this research, we progressively realized that the patient has to be regarded as an integral part of the medication communication loop, and IT needs to address a suitable way to incorporate the role of patient into that of healthcare providers.

In Chapter 5, we touched upon different challenges to building a national interoperable network for medication data communication [13]. We argued that such large-scale development requires changes to the information infrastructure of participant organizations. Important differences in cultural, financial, technical, political, legal, ethical, and organizational aspects between participant organizations affect the process of change adoption and challenge the building of an interoperable communication network. We examined two different approaches – centralized vs. decentralized – for dealing with these issues and creating such a large-scale construction within the Dutch healthcare system. Each approach faced diverse challenges to the integration of heterogeneous information systems. We analyzed the dynamics within these challenges and concluded that the key issue has to do with the integrating of the medication-related activities seen on the "work floor" of the participant organizations. For IT to be able to close the loop and to build interoperability, the medication-related work of care providers in the stakeholder organization must be spelled out and linked, and it must be clearly defined as to who should do what and when in the communication loop. We argued that the integration challenge can be better addressed at the decentralized level and that the best solution has to emerge from both the centralized and decentralized approaches.

To conclude, in intra-organizational communication, a high level of integration is gradually developed between different pieces of work (i.e., practical integration). Interoperability is challenged mainly because IT cannot support the required communication for this level of work integration and collaboration. Thus, in implementation of information systems to support highly collaborative work processes, the probable difficulties in interoperability of system users have to be discovered and compensated. In inter-organizational communication, on the other hand, there is yet no agreed upon integration strategy in place (i.e., theoretical integration) and related work of participant organizations is not integrated. Thus, the absence of the necessary level of work integration is the primary challenge to be met for the building of interoperable communication networks. Moreover, our study suggests that evaluations of IT systems with regard to patient safety should have a longer focus than the normal pre-post designs, as workarounds develop over time in response to specific practical problems.

These findings do not provide a straightforward answer to the main research question: "How can information technology be applied to improve intra- and inter-organizational communication in healthcare without jeopardizing patient safety?" Nevertheless, they do contribute to an understanding of the dynamics between healthcare processes and IT interventions. We raised important implications that can be useful for the safe and successful application of ICT in healthcare communication. Nevertheless, there are many open research questions to be addressed if healthcare is to benefit even more from ICT, and if the negative impacts of ICT on patient safety are to be prevented. These questions include: How should feedback and synchronization mechanisms be built into IT systems that are going to be implemented in collaborative processes? How should the ongoing development of workarounds in the dynamic environment of healthcare be managed in order for them not to harm patients? What is the best combination of centralized and decentralized approaches in building a large-scale inter-organizational communication network? How should information technology be applied in order to integrate different stakeholders' roles and work in this network?

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SUMMARY

English Summary

Healthcare systems increasingly need better and efficient system of communication. Such communication has to provide healthcare organizations and healthcare providers with reliable, fast, and safe ways of exchanging patient information. Information technology has much potentiality to serve healthcare communication. However, healthcare organizations have attributes which challenge successful application of IT systems to support healthcare processes and to improve communication and patient safety. This thesis looks at the interaction of those attributes with IT systems in the process of medication work. Apart from studying how organizational factors affect IT systems implementation and use, throughout this thesis, we search for ways to solve the conflicts, and to reduce unintended negative consequences.

Since intra-organizational communication accounts for the majority of healthcare communication, Chapter 1 discusses current healthcare-related intra-organizational communication problems that lead to errors in healthcare practice. Looking specifically at problems associated with the standardization of healthcare practices and we ask how ICT applications might or might not be beneficial for intra-organizational communication. Through analyzing the literature, four possible scenarios are defined on how ICT can serve healthcare communication and two differing conceptual frameworks about communication in healthcare are elaborated upon. In this chapter, we argue that successful communication in healthcare amounts not only to interoperable systems but also to interoperable professionals working in care practice. It aims at gaining "mutual intelligibility" or "shared understanding" between human communicators in organizing patient care. The chapter concludes that parallel to conventional standardization, at least three dimensions need to be addressed: controlling the effect of the social context, developing standard information processing skills, and most importantly, controlling variations in care practices' performance. The theoretical framework developed in this chapter is used to Chapters 2 and 3 to analyze the use of IT systems in healthcare practices.

Chapter 2 evaluates the impact of a CPOE system on nurse-physician communication on the medication process. In six internal medicine wards, the effect of the system on building interoperability in the medication-related collaboration between nurses and physicians is assessed by two pre- and post-implementation surveys and 15 interviews (with 9 nurses and 6 physicians). The total response rates were 54.3% and 52.1% for pre- and post-implementation questionnaires. T-tests show that after implementation the legibility and completeness of prescriptions were significantly improved ($P<0.001$) and the

administration system had a more intelligible layout (P<0.001), with a more reliable overview (P<0.001) and clearer records (P=0.027). The interviews supported quantitative findings. They, nevertheless, showed communication problems that caused difficulties in linking medication work of nurses to that of physicians. To compensate for these, nurses and physicians devised informal interactions and practices ('workarounds'), which often caused risks for medication errors. We conclude that the system introduced many communication problems and workflow impediments to the medication process. Workarounds due to these impediments can contribute to the error induction effect of a CPOE system. In order to prevent such an effect, CPOE systems have to support the level of communication which is necessary to integrate the work of nurses and physicians.

In Chapter 3, we deepen our insight and search to answer the questions: Which mechanisms in nurse-physician communication are affected by the switch from a paper-based to a CPOE medication system? And how do the affected mechanisms impact nurse-physician collaborative medication work? Again data came from two pre- and post-implementation surveys and 15 semi-structured interviews with nurses (N=9) and physicians (N=6). Response rates for the analyzed questions in the pre- and post-implementation questionnaires were 54.3% (76/140) and 52.14% (73/140) respectively. The CPOE system had a mixed impact on medication work: while it improved the main non-supportive features of the paper-based system, it lacked its main supportive features. The interviews revealed more detailed supportive and non-supportive features of the two systems. A comparison of supportive features of the paper-based system with non-supportive features of the CPOE system showed that synchronization and feedback mechanisms in nurse-physician collaborations have been impaired after the CPOE system was introduced. The Chapter concludes with recommendations for repairing the impaired mechanisms and for redesigning the CPOE system to support these mechanisms.

In Chapter 4 and 5 the focus of the study is shifted from intra-organizational to inter-organizational communication. In Chapter 4, we search to understand what may challenge building an interoperable communication network between healthcare organizations through IT systems. The chapter is a case study of the building of a regional inter-organizational communication network between primary and secondary healthcare for the exchange of medication data. We focus on challenges to the integration process and to the building of an interoperable communication network. Interviews, document analysis, and observations were conducted to evaluate the integration process in a project that involved medication data communication between primary healthcare providers (i.e., general practitioners and community pharmacists) and secondary healthcare providers (i.e., hospital pharmacists and specialist physicians). The project encountered numerous integration problems, many of which persisted even after extensive technical intervention. An analysis of the problems revealed that they were mostly rooted either in problematic integration of work processes or in the way the system was used. Despite the project's ideal technical condition, the integration could be accomplished only by applying human interfaces. The chapter concludes that the main challenge to building interoperable communication network lies in implementing technical linkages without the work processes being aligned and integrated.

Chapter 5 evaluates challenges and complexities involved in building an Inter-Organizational Communication Network (IOCN) in healthcare and the required appropriations in the strategies. Interviews, literature review, and document analysis were conducted to analyze the developments that have taken place toward building a countrywide electronic patient record and its challenges in The Netherlands. Due to the interrelated nature of technical and non-technical problems, a socio-technical approach was used to analyze the data and define the challenges. Organizational and cultural changes are necessary before technical solutions can be applied. There are organizational, financial, political, and ethicolegal challenges that have to be addressed appropriately. Two different approaches, one "centralized" and the other "decentralized" have been used by Dutch healthcare providers to adopt the necessary changes and cope with these. We conclude that the best solutions in building an IOCN have to be drawn from both the centralized and the decentralized approaches. Local communication initiatives have to be supervised and supported centrally and incentives at the organizations' interest level have to be created to encourage the stakeholder organizations to adopt the necessary changes.

In conclusion, we get back to our research question "How can information technology be applied to improve intra- and inter-organizational communication in healthcare without jeopardizing patient safety?" We argue that in intra-organizational environments, practical integration is gradually developed between different pieces of work over time. IT cannot support the required communication for this level of work integration and collaboration and challenges users' interoperability. Thus, in implementation of information systems into highly collaborative work environments, the probable difficulties in interoperability of the users have to be analyzed and compensated. In inter-organizational communication, on the other hand, there is yet no agreed upon theoretical integration in place and related work of participant organizations is not integrated practically. Thus, the absence of the necessary level of work integration is the primary challenge to be met for the building of interoperable communication networks.

Dutch Samenvatting

Er is in de gezondheidszorg behoefte aan betere en efficiënte communicatiesystemen die zorgprocessen ondersteunen en die communicatie en patiëntenveiligheid verbeteren. Zulke systemen dienen zorgorganisaties en –professionals te voorzien van betrouwbare, snelle en veilige manieren om patiënteninformatie uit te wisselen. Informatietechnologie biedt een rijk potentieel om betere communicatie in de gezondheidszorg te faciliteren. De complexiteit van zorgorganisaties staat echter vaak op gespannen voet met de succesvolle invoering van IT systemen. Dit proefschrift bestudeert de interactie van deze kenmerken en IT systemen in het proces van medicatiewerk. Naast het onderzoek naar organisatorische factoren die de implementatie van IT systemen beïnvloeden, kijken wij in dit proefschrift ook naar manieren om de geanalyseerde conflicten op te lossen en om onbedoelde negatieve effecten te beperken.

Omdat intra-organisatorische communicatie het leeuwendeel van de zorgcommunicatie omvat, behandelt Hoofdstuk 1 de stand van zaken in zorggerelateerde intra-organisatorische communicatieproblemen die resulteren in fouten in zorgpraktijken. Door met name te kijken naar problemen die voortkomen uit de standaardisering van zorgpraktijken, stellen wij de vraag hoe ICT applicaties intra-organisatorische communicatie al dan niet gunstig kunnen beïnvloeden. Door literatuurstudie worden er vier scenario's gedefinieerd die aangeven hoe ICT zorgcommunicatie mogelijkerwijs kan versterken en worden twee verschillende conceptuele kaders over zorgcommunicatie uitgewerkt. In dit hoofdstuk stellen wij dat succesvolle communicatie in de gezondheidszorg niet alleen neerkomt op technisch interoperabele systemen maar ook sterk afhankelijk is van 'interoperabele professionals' die in een zorgpraktijk werkzaam zijn. Zulke communicatie streeft er dus naar "wederzijds begrijpelijk" te zijn en te leiden tot "gedeeld begrip" tussen menselijke communicatoren bij de organisatie van patiëntenzorg. Het hoofdstuk concludeert dat er naast reguliere standaardisering tenminste drie dimensies moeten worden behandeld: het beheersen van consequenties van en in de sociale context, het ontwikkelen van standaard vaardigheden om informatie te verwerken en, als allerbelangrijkste, het beheersen van variatie in de performance van zorgpraktijken. Het theoretisch kader dat in dit hoofdstuk wordt ontwikkeld, wordt gebruikt in de hoofdstukken 2 en 3 om het gebruik van IT systemen in zorgpraktijken te analyseren.

Hoofdstuk 2 evalueert de gevolgen van een CPOE (*computerized physician order entry*) systeem voor de communicatie over het medicatieproces tussen verpleegkundigen en artsen. Het effect van het systeem voor het creëren van interoperabiliteit in de medicatiegerelateerde samenwerking tussen verpleegkundigen en artsen wordt onderzocht op zes afdelingen interne geneeskunde in twee pre- en post-implementatie vragenlijsten en 15 interviews (met 9 verpleegkundigen en 6 medisch specialisten). De vragenlijsten gaven aan dat de leesbaarheid en volledigheid van voorgeschreven medicatie significant was verbeterd na implementatie van het systeem en dat het registratiesysteem een begrijpelijker layout had, met een betrouwbaarder overzicht en duidelijker dossiers. De interviews bevestigden de kwantitatieve resultaten. Daarnaast kwamen hieruit echter ook communicatieproblemen naar voren die ertoe leidden dat het moeilijker bleek om het medicatiewerk van verpleegkundigen aan dat van artsen te koppelen. Om deze problemen weg te nemen ontwikkelden verpleegkundigen en artsen informele interacties en praktijen (‘omwegen’), die vaak tot nieuwe risico’s leidden op het gebied van medicatiefouten. We concluderen dat het systeem veel medicatieproblemen introduceerde en tot beperkingen leidde in de werkpraktijk rondom het medicatieproces, ondanks de positieve bijdragen die het systeem ook had. Omwegen die bedacht werden om deze beperkingen te omzeilen kunnen ertoe leiden dat het CPOE systeem zelf nieuwe fouten introduceert. Om zulke consequenties te voorkomen moeten CPOE systemen de communicatie ondersteunen die noodzakelijk is om het werk van verpleegkundigen en artsen te integreren.

In Hoofdstuk 3 verdiepen wij ons inzicht door een antwoord te zoeken op de vragen: welke mechanismen in de communicatie tussen verpleegkundigen en artsen worden er beïnvloed door de overgang van papieren medicatiesystemen naar een CPOE systeem? En hoe hebben de betreffende mechanismen invloed op het samenwerkingsproces tussen verpleegkundigen en artsen in het medicatieproces? Ook hier kwamen de gegevens uit twee pre- en post-implementatie vragenlijsten en uit 15 semi-gestructureerde interviews met verpleegkundigen (N=9) en medisch specialisten (N=6). De uitkomsten van de vragenlijsten lieten zien dat het CPOE systeem een gemengd effect had op het medicatiewerk: hoewel het tot verbeteringen leidde in de niet-ondersteunde onderdelen van het papieren systeem, ontbeerde het de belangrijkste ondersteunende aspecten. De interviews gaven een gedetailleerder inzicht in de aspecten die wel en niet ondersteund werden door de twee systemen. Een vergelijking van ondersteunende aspecten van het papieren systeem met de niet-ondersteunde aspecten van het CPOE systeem liet zien dat mechanismen voor afstemming en voor feedback beperkt werden door de introductie van het CPOE systeem. Het hoofdstuk concludeert met aanbevelingen om deze beperkingen voor deze mechanismen te repareren en om het CPOE systeem zo te herontwerpen dat het deze mechanismen ondersteunt.

In Hoofdstuk 4 en 5 wordt de aandacht van het onderzoek verlegd van intra-organisatorische naar interorganisatorische communicatie. In Hoofdstuk 4 onderzoeken we wat de uitdagingen zijn voor het ontwikkelen van een interoperabel communicatienetwerk tussen zorgorganisaties door de inzet van IT systemen. Dit hoofdstuk bespreekt de casus van het ontwikkelen van een regionaal communicatienetwerk voor de uitwisseling van medicatiegegevens tussen eerste- en tweedelijns zorginstellingen. Wij richten ons op uitdagingen in het integratieproces en op het ontwikkelen van een interoperabel communicatienetwerk. Hiertoe werden interviews afgenomen, documenten geanalyseerd en observaties gedaan van het integratieproces in een project dat betrekking had op het communiceren van medicatiegegevens tussen eerstelijns zorgverleners (zoals huisartsen en locale apotheken) en tweedelijns zorgverleners (zoals ziekenhuisapotheken en medisch specialisten). Het project liep tegen verscheidene integratieproblemen aan, waarvan er vele hardnekkig aanwezig bleven, ook na uitgebreide technologische aanpassingen. Een analyse van de problemen onthulde dat ze veelal voortkwamen uit een problematische integratie van werkprocessen en de manier waarop het systeem werd gebruikt. Ondanks de ideale technologische omstandigheden van het project kon de integratie alleen gerealiseerd worden door menselijke tussenpersonen te gebruiken. Dit hoofdstuk concludeert dat de grootste uitdaging voor het bouwen van een interoperabel communicatienetwerk erin schuilt om technologische connecties zodanig te ontwikkelen en te implementeren dat de integratie en afstemming van werkprocessen ermee ondersteund wordt.

Hoofdstuk 5 evalueert veranderingen en complexiteiten betreffende de ontwikkeling van een interorganisatorisch communicatienetwerk (IOCN) in de zorg en de daarbij behorende strategische aanpassingen. Hiertoe werden interviews afgenomen, werd literatuurstudie verricht en werden documenten geanalyseerd om de ontwikkelingen te analyseren die dienen te leiden tot een landelijk dekkend elektronisch patiëntendossier in Nederland. In aansluiting op de aard van deze activiteiten, waarbij technische en niet-technische problemen samenkomen, is gekozen voor een sociotechnische aanpak om deze gegevens te analyseren en om de uitdagingen te definiëren. Organisatorische en culturele veranderingen zijn nodig voordat technische oplossingen kunnen worden toegepast. Er zijn organisatorische, financiële, politieke en ethische uitdagingen die adequaat behandeld moeten worden. In Nederland kunnen twee verschillende aanpakken worden onderkend die zijn gevolgd om de nodige aanpassingen over te nemen en te accommoderen: een “gecentraliseerde” en een “gedecentraliseerde” aanpak. Beide strategieën kennen hun voor- en nadelen en een combinatie van beide strategieën is nodig om deze te vermijden. Lokale communicatie-initiatieven moeten begeleid en ondersteund worden vanuit centraal niveau en er moeten prikkels worden gecreëerd op het niveau van de belangen van instellingen om ervoor te zorgen dat belanghebbende organisaties de noodzakelijke veranderingen overnemen.

Concluderend keren we terug naar onze onderzoeksvraag: “Hoe kan informatietechnologie toegepast worden om intra- en interorganisatorische communicatie in de gezondheidszorg te verbeteren zonder daarbij de patiëntenveiligheid in gevaar te brengen?” We stellen dat in intra-organisatotische omgevingen praktische integratie incrementeel ontwikkeld kan worden tussen verschillende onderdelen van het werk in de loop van de tijd. IT kan geen bijdrage leveren aan de vereiste communicatie op het niveau van de integratie van het werk en de samenwerking en stelt de interoperabiliteit van gebruikers op de proef. Gebruikers ontwikkeld hierdoor ‘omwegen’ die uiteindelijk negatieve consequenties hebben voor de patiëntveiligheid. Daarom dienen, bij de implementatie van informatiesystemen in sterk op samenwerking gerichte werkomgevingen, de knelpunten betreffende de interoperabiliteit van de gebruikers geanalyseerd en gecompenseerd worden. Daarentegen geldt voor interorganisatorische communicatie dat er nog geen sprake is integratie en het betreffende werk van deelnemende organisaties in de praktijk, maar dat deze in de ontwikkeling en implementatie van het systeem ontwikkeld moeten worden. Daarom is de afwezigheid van de benodigde integratie van werkzaamheden de grootste uitdaging voor de ontwikkeling van interoperabele communicatienetwerken.

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Habibollah Pirnejad
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CURRICULUM VITAE

Habibollah Pirnejad was born on April 9, 1968 in Urmia city, in northwest of Iran.

In 1987, he graduated from Maanavi High School, in Urmia. In 1988, he studied Medical Laboratory Sciences at ‘Iran Medical Science University’, in Tehran. After graduating with Associated Degree in 1991, he worked in a hospital laboratory in Urmia for two years. In 1993, he started studying Medicine at ‘Shahid Beheshti Medical Science University’ in Tehran, but later he moved to ‘Urmia Medical Science University’. During his medical curriculum, he was awarded the 1st rank in Medical Basic Sciences in 1995 and the 5th rank in Clinical Sciences in 1997, among the university medical students. He was granted the title of the best medical student of the University in 1997. He graduated in Medicine in 1999 and worked as a General Practitioner in a very deprived area in Kurdestan, Iran for 2 years. In 2001, he was awarded a scholarship from Urmia Medical Science University to pursue his study abroad in Medical Informatics.

He moved to The Netherlands in July 2003 and started the International Master of Health Information Management at Erasmus University Rotterdam. In 2005, he graduated from the master program and worked as a PhD fellow at the Institute of Health Policy and Management, Erasmus MC. During his PhD trajectory, he involved in evaluating a number of IT projects, including TUMA and Medicator. He currently works as a researcher at the department of Healthcare Governance of Erasmus MC.

He married to Zahra Niazkhani in 1998 and they have a daughter, Samin Pirnejad.