Department of Computer Science and Engineering

Usability in Healthcare: Overcoming the Mismatch between Information Systems and Clinical Work

Johanna Kaipio (nee Viitanen)

Aalto University

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Usability in Healthcare: Overcoming the Mismatch between Information Systems and Clinical Work

Johanna Kaipio (nee Viitanen)

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Abstract

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Abstract

Usability of clinical information technology (IT) systems is an ongoing topic of discussion. The systems should support healthcare professionals in their daily work with patients. However, critics indicate the prevalence of negative experiences and use related problems.

The overall goal of the thesis is to examine the usability of current clinical IT systems from the viewpoint of physicians and nurses for the purposes of further user-centred system development. The thesis includes three empirical studies: a digital dictation study, evaluation of nursing documentation systems, and a national usability questionnaire study with physicians. The research was carried out utilizing contextual inquiry, interaction sequence illustration analysis, and tailored usability questionnaire methods.

The research resulted in the following findings and conclusions.

Currently used IT systems do not support the daily work and clinical tasks of clinicians well. This is due to numerous usability problems, and lack of computer support for multi-professional and cross-organizational collaboration between clinicians. Major improvements are needed to achieve the potential benefits clinical information and communication technology systems offer. Based on empirical studies, themes for potential improvements are: development of efficient and mobile documentation solutions, redesign of system user interfaces, solutions to support communication and collaboration, customisable and context-specific clinical IT systems, and conceptual redesign of nursing documentation system.

In the field of health informatics, a need exists to broaden the scope of usability work. Usability is closely associated with evaluation and testing activities instead of design activities. Hence, the scope of usability is more restricted than it is in user-centred design and usability research fields. In order to overcome the current mismatch between IT systems and clinical work, it is important to understand that usability is extremely context-sensitive by nature.

The study results indicated shortcomings in user-centred healthcare IT systems design and end-users' abilities to contribute to development work. User-centred design methods provide a variety of means to analyse, design, and evaluate information and communication systems for clinical purposes. However, the characteristics of the clinical context (e.g. privacy and data security issues, and the wide range of IT systems in use) need to be taken into account when applying the methods and performing research in real-life clinical surroundings.

Keywords Usability, clinical information and communication technology (ICT) systems, user-centred design, healthcare information system development, clinical work, physician, nurse

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Tekijä
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Käytettävyys terveydenhuollossa: Tavoitteena tietojärjestelmien ja potilastyön yhteensovittaminen

Julkaisija Perustieteiden tiedekunta

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Tiivistelmä

Terveydenhuollon tietojärjestelmien käytettävyys on ajankohtainen puheenaihe. Järjestelmien tulisi tukea terveydenhuollon ammattilaisia heidän päivittäisissä työtehtävissään. Käytännön kokemukset ja havainnot ovat kuitenkin nostaneet esiin ongelmia ja puutteita.

Tässä väitöskirjassa tutkitaan potilastyössä hyödynnettävien tietojärjestelmien käytettävyyttä lääkärien ja hoitajien näkökulmasta. Tutkimuksen tavoitteena on tukea järjestelmien käyttäjälähtöistä kehittämistä. Työ sisältää kolme empiiristä tutkimusta: digitaalinen sanelu -tutkimus, hoitotyön kirjaamisjärjestelmien arviointi, sekä tietojärjestelmien käyttökokemuksia kartoittava kyselytutkimus lääkäreille. Tutkimusmenetelminä käytettiin tilannesidonnaista haastattelua, käyttöliittymätason vuorovaikutusanalyysiä ja räätälöityä käytettävyyskyselyä.

Työn keskeisimmät tulokset ovat seuraavat.

Nykyiset potilastyössä käytettävät tietojärjestelmät eivät tue lääkärien ja hoitajien arkityötä. Käytettävyysongelmat haittaavat järjestelmien tehokasta käyttöä, lisäksi järjestelmien tulisi nykyistä paremmin tukea moniammatillista ja eri organisaatioissa työskentelevien ammattilaisten välistä yhteistyötä. Järjestelmien myötä tavoiteltujen hyötyjen saavuttaminen vaatii mittavia kehittämistoimia. Kehittämistyön tulisi keskittyä tehokkaiden ja mobiilien kirjaamisratkaisujen toteuttamiseen, potilastietojärjestelmien käyttöliittymien uudelleensuunnitteluun, ammattilaisten välistä vuorovaikutusta ja yhteistyötä tukevien sovellusten kehittämiseen, räätälöitävien ja yksikkökohtaisesti sovitettavien järjestelmien toteuttamiseen, sekä hoitotyön kirjaamisjärjestelmän uudelleensuunnitteluun konseptitasolla.

Terveydenhuollon tietojärjestelmätutkimuksen alueella käytettävyystyön ulottuvuuksia tulisi laajentaa. Nykyinen arviointikeskeinen painotus on rajallisempi kuin mitä käytettävyystutkimuksen ja käyttäjäkeskeisen suunnittelun alueilla vallitseva suunnittelupainotteinen lähestymistapa. Käytettävyys on kontekstisidonnainen ominaisuus. Tämän ja käyttäjien tarpeisiin liittyvän ymmärryksen tulisi olla potilastyöhön kehitettävien tietoteknisten työvälineiden suunnittelun lähtökohtana.

Tutkimus osoittaa, ettei käyttäjänäkökulmaa ole huomioitu riittävästi terveydenhuollon tietojärjestelmien kehittämistyössä. Käyttäjäkeskeisen suunnittelun menetelmiä voidaan hyödyntää järjestelmien suunnittelussa ja arvioinnissa. Tämä vaatii kuitenkin menetelmien soveltamista muun muassa seuraavat potilastyön erityispiirteet huomioiden: potilaiden yksityisyydensuoja ja tietoturva, sekä lukuisia tietojärjestelmiä sisältävä työskentely-ympäristö.

Avainsanat Käytettävyys, terveydenhuollon tieto- ja viestintätekniset järjestelmät, käyttäjäkeskeinen suunnittelu, terveydenhuollon tietojärjestelmäkehitys, potilastyö, lääkäri, hoitaja

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Preface

I wish I could help people in a way that physicians and nurses do. But engineers do not have such knowledge and skills. Therefore, my mission is to support the development of appropriate and effective healthcare information and communication tools with high usability.

This thesis work has taken some time, not too many years but enough. There are many to thank for collaboration and support.

I would especially like to thank Professor Marko Nieminen for his support during our shared trip that started in 2004. Thank you for friendship, collaboration in research actions, co-authoring research articles, and valuable comments and guidance regarding this thesis. Many thanks also to my instructor Sakari Tamminen for support, guidance, and discussions. I would also like to thank Morten Hertzum and Timo Jokela for their pre-examination comments.

In addition, I wish to thank colleagues working in healthcare technology research: Tinja Lääveri, Pirkko Nykänen, Hannele Hyppönen, Susanna Martikainen, Anne Kuusisto, Jukka Vänskä, Ilkka Winblad, Mikko Korpela, Jarmo Reponen, and Marko Elovainio.

While working at SoberIT and at Strategic Usability Research Group for about seven years, I have had many interesting and inspiring discussions with numerous people. Special thanks to Mika Nieminen, Sirpa Riihiaho, Petri Mannonen, Mikael Runonen, Sampo Teräs, Lasse Lumiaho, Mari Tyllinen, Jussi Rämänen, Tapio Haanperä, Timo Itälä, Matti Hämäläinen, Katja Laurinolli, and Jonna Lehtola, as well as to Fiona Wilson for her help in proofreading the articles.

I would also like to express my gratitude for the thesis work funding from Työsuojelurahasto (The Finnish Work Environment Fund) and Instrumentariumin tiedesäätiö (The Instrumentarium Science Foundation).

Last but not least, I would like to express my sincerest appreciation for my beloved ones: Otto, my parents Päivikki and Eero, as well as Arttu, Emmi, and Lauri. Thank you for your support, patience, and hugs.

Espoo, 5.10.2011

Johanna Kaipio

List of Publications

The following papers are included in this thesis. The publications are written under the author's maiden name Viitanen.

Paper I: Viitanen, J. (2009) Redesigning Digital Dictation for Physicians: A User-Centred Approach. Health Informatics Journal 15 (3), pp. 179-190.

Paper II: Viitanen, J., Kuusisto, A., Nykänen, P. (2011) Usability of Electronic Nursing Record Systems: Definition and Results from an Evaluation Study in Finland. In Borycki E.M., Bartle-Clar J.A., Househ M.S., Kuziemsky C.E., Schraa E.G. (eds.), International Perspectives in Health Informatics. Studies in Health Technology and Informatics 164, pp. 333-338.

Paper III: Viitanen, J. (2011) Contextual Inquiry Method for User-Centred Clinical IT System Design. In Moen A. et al. (eds.), "User Centred Networked Health Care", Studies in Health Technology and Informatics 169, pp. 965-969.

Paper IV: Viitanen, J., Hyppönen, H., Lääveri, T., Vänskä, J., Reponen, J., Winblad, I. (2011) National Questionnaire Study on Clinical ICT Systems Proofs: Physicians Suffer from Poor Usability. International Journal of Medical Informatics 80(10), pp. 708-725.

Paper V: Martikainen, S., Viitanen, J., Korpela, M., Lääveri T. (2011) Physicians' Experiences of Participation in Healthcare IT Development: Willing but not Able. International Journal of Medical Informatics (in press, doi: http://dx.doi.org/10.1016/j.ijmedinf.2011.08.014).

Paper VI: Viitanen, J., Nieminen, M. (2011) Usability Evaluation of Digital Dictation Procedure – An Interaction Analysis Approach. Lecture Notes in Computer Science 7058, Springer (2011) (in press).

Author's Contribution

Paper I 'Redesigning Digital Dictation for Physicians: A User-Centred Approach' reports a study that employed a contextual inquiry method to research physicians' dictation practices with three techniques (cassette, digital, and voice recognition dictation) in the hospital environment. Viitanen was responsible for data gathering and analysis, as well as for planning and writing of the article. An earlier version of this article was published in the International Symposium for Healthcare Information Management Research proceedings from 2008 (ISHIMR 2008).

Paper II 'Usability of Electronic Nursing Record Systems: Definition and Results from an Evaluation Study in Finland' describes the summative results from a usability evaluation study of four electronic nursing documentation systems. The study was part of a larger research project conducted by a group of three researchers: professor Nykänen and researchers Viitanen and Kuusisto. The group designed and conducted the research project together. Viitanen was responsible for planning and writing of the article, the other authors provided input and commented the article during its preparation.

Paper III 'Contextual Inquiry Method for User-Centred Clinical IT System Design' reports experiences from two empirical studies (described in papers I and II) in which contextual inquiry was applied to gather information about user needs in clinical contexts. The paper was planned and written by Viitanen.

Paper IV 'National Questionnaire Study on Clinical ICT Systems Proofs: Physicians Suffer from Poor Usability' introduces usability results for clinical information and communications technology (ICT) systems, particularly electronic health records (EHRs), from a national questionnaire study of clinical physicians. The study was planned and conducted in a multidisciplinary group, and the work included the design of the questionnaire items and gathering of data. Viitanen participated in the group as a usability specialist and carried out pilot tests. Viitanen was the main author of the paper and responsible for the entirety of its content, including conception, and design and (theoretical) conceptual background related to usability, data interpretation, generation of drafts and revisions, and final approval of the article.

Paper V 'Physicians' Experiences of Participation in Healthcare IT Development: Willing but not Able' is written based on a set of qualitative and quantitative data gathered from a national questionnaire project (see paper IV) in spring 2010. Viitanen participated in creation of the study design, planned the paper, and analysed the qualitative data in cooperation with Martikainen. Viitanen was mainly responsible for writing the introductory and study procedure parts of the paper, as well as for conducting statistical analysis and reporting the related findings.

Paper VI 'Usability Evaluation of Digital Dictation Procedure – An Interaction Analysis Approach' introduces interaction sequence illustration (ISI), a task- and context-originating modelling method for the analysis of interaction steps and stages in the context of healthcare. In the paper, the experimental employment of an ISI method is illustrated using digital dictation study as an example. Nieminen and Viitanen planned the original version of the paper together; this version was submitted to the Engineering Interactive Computer Systems conference, but rejected. Viitanen revised the paper based on reviewers' comments, and was responsible for finalising the paper for submission to the USAB 2011 conference and for publication in Lecture Notes in Computer Science series.

Table of Contents

1 INTRODUCTION

> *We can make systems that help healthcare professionals do their work better: providing reminders, allowing free and fast communication, allowing fast access to patient information and so forth. ... On the other hand, we can also make systems that require meticulous data entry for the sake of "completeness", or that help managers' overview and control the work of professionals.*

The statement by Marc Berg (2002) illustrates the original developmental aims of clinical information and communication technology (ICT) systems. One primary goal should exist for clinical ICT development: systems should be supportive of healthcare professionals in their daily work with patients. This entails providing users of ICT systems with appropriate tools and facilitating the ease and efficiency with which clinical tasks are performed. On the other hand, this single goal, and the characteristics such an ICT system must have to support the goal, clearly outlines the challenges underlying development, adoption, and use of clinical ICT systems. Instead of supporting professionals in clinical tasks, the systems may create additional work and primarily serve secondary users and purposes of use.

In the health informatics research field, the need for a good fit between interactive systems and practices for providing routine patient care is recognised as essential (e.g. Reuss et al., 2007a; Nykänen and Karimaa, 2006). Nevertheless, relatively little is found in the literature on the question of user-centred design and development of healthcare ICT systems. For example, the concept of *usability of healthcare information systems* has been presented with a variety of meanings in articles by researchers such as Fairbanks and Caplan (2004), Svanæs et al. (2008), and Belden et al. (2009); however, researchers have not described the contextual aspects or the characteristics or attributes of usability that are important to address when researching usability of ICT systems in the healthcare contexts. Further, only a few researchers have systematically investigated the benefits and barriers of user involvement in healthcare technology development. The review by Shah and Robinson (2007) found some key impediments to user involvement being lack of resources, attitudes of technical developers, and lack of understanding and appropriate knowledge about methods to be used (Shah and Robinson, 2007).

1.1 A Gap between Investments and Expected Benefits

Today, healthcare IT covers a wide range of applications and services targeted for a variety of users and purposes of use. Information systems have a key role in patient care – both stand-alone and integrated applications are widely implemented and adopted. As befits the wide adoption of healthcare ICT systems, healthcare providers invest considerable resources in these systems. The Finnish municipalities, which are funded by taxation and have the primary responsibility of arranging social and healthcare services in their respective areas, paid €400 million in information technology (IT) costs in 2009 (STM, 2010)[1]. To further develop the Finnish example, the district of Helsinki and

[1] Population in Finland in 2010 was about 5.4 million.

Uusimaa planned to invest €10 million on IT development during the year 2010, of which nearly €6 million was targeted to further development of currently used electronic health record (EHR) systems (HUS Administration, 2009)[2]. Furthermore, the estimated costs for maintaining the national health archives in Finland are €200 million for the 12-year period 2003-2014 (STM, 2010; STM, 2011). The total costs of a similar national project in United Kingdom are estimated at £12.7 billion (nearly €15 billion) (National Audit Office, 2008). These examples raise the question of expected technology benefits. What are the main reasons for implementing the systems? For whom and for what kind of use are they developed? What kind of effects is IT expected to have on the delivery of care and the daily work of healthcare professionals?

According to literature new technology solutions in hospitals and healthcare centres are expected to improve the quality and efficiency of care. In fact, workflow improvement and operations streamlining are publicly stated to be the anticipated effects of the implementation of new technology upon proper integration of the systems (Beaver, 2003). The practical effects of new healthcare technology adaptation are, however, described to be manifold.

While the purported end goal of most healthcare ICT systems is described in terms of facilitating care and overall simplicity of operations (i.e., through workflow improvements), the practical effects of the adaptation of new healthcare technology are manifold; not all of them have been positive. Review studies have pointed out the serious challenges in the adaptation and development of information systems (e.g. Poissant et al., 2005; Chaudhry et al., 2006; Häyrinen et al., 2008; Black et al., 2011), as well as in evaluation of the evidence on the benefits, savings, and costs of adopting healthcare IT (Congressional Budget Office, 2008; Pirttivaara, 2010). For example, based on their systematic literature review André et al. (2008) reported the following barriers to the adoption of information systems in healthcare: negative attitudes, lack of knowledge, role adjustments related to the disruption of traditional work habits, and changes in established work roles. Empirical studies have indicated that the most significant barriers in EHR system adoption and use are concerns about the amount of time it takes to use the system (Meade et al., 2009; Linder et al., 2006; Likourezos et al., 2004). In addition, reliable estimates of the total and local costs of national health archive projects are difficult to produce, as these projects have faced serious challenges and as a result have been delayed for several years) (National Audit Office, 2008; STM, 2010; STM, 2011) (the current estimate for the completion of the Finnish initial development is 2014) (STM, 2010; STM, 2011).

Some positive findings have also been reported with respect to healthcare IT adoption. Reviews show that in hospitals, information systems have improved quality of care by increasing adherence to guidelines, enhancing disease surveillance and quality of documented data, and decreasing medication errors (Chaudhry et al., 2006; Black et al., 2011). In their simulation study Hertzum and Simonsen (2008) investigated the effects of a fully integrated clinical-process EHR on clinicians' work during team conferences,

[2] In year 2010, the total number of citizens who used services provided by Hospital district of Helsinki and Uusimaa was 465014. (Reference: Statistics available online: http://www.hus.fi/default.asp?path=1,28,2052 [accessed 05/05/2011]).

ward rounds, and changes in shift for nurses. The simulation arrangements included replacement of all paper records, and continuous monitoring and operation of the EHR system so that the clinicians in the stroke unit experienced the system as fully supporting all transactions. Experiences with the system indicated reduction of the mental workload for clinicians, increased clarity of physicians' work tasks, and (during nursing handovers) more support for information delivery compared to the support available with paper records (Hertzum and Simonsen, 2008). With these encouraging findings, the researchers pointed out that such systems are not expected to be in operational use in Denmark until at least 2 years after conclusion of their study (2008).

To summarise, these results on negative, positive, and promising findings emphasise the need for further research to realise the practical benefits and challenges behind the adaptation of IT for use in healthcare. Several review articles have also reported the evidence of the cost of benefits of IT, and argued the need for further research (Chaudhry, 2006; Häyrinen et al., 2008; Congressional Budget Office 2008; Black et al., 2011).

1.2 Complications in Healthcare IT Adoption and Use

The success of healthcare IT is an on-going topic of discussion. In Finland, the debate has occurred at several levels for sectors related to healthcare sectors and in various forums ranging from academic publications to public forums. The critiques emerging from these forums indicate the prevalence of negative experiences with healthcare IT, and of inadequate performance of these systems in supporting clinicians' daily work. Figure 1 illustrates a collection of titles and topics of recent newspaper articles. (The titles have been translated from Finnish by the author and the references to articles can be found from reference list).

Healthcare wants to get rid of incomplete systems
(Strann, L., *Tiedon silta magazine* 02/2007)
Patient safety is more and more an IT challenge
(Vuorenmaa, T., Kontio, J., *Helsingin Sanomat newspaper*, 02/02/2008)
A single health record system is a viable option
(Sitra - the Finnish Innovation Fund, *electronic news letter in Sitra's www-page*, 12/01/2011)
Study on usability of electronic health record systems shows: Physicians' opinions have been ignored
(Lääveri, T. Finnish Medical Journal No 6, 2008)
More than half of working time in specialised healthcare is wasted on paper work
(Kaarto, H., *Helsingin Sanomat newspaper*, 11/12/2008)
Users' opinions were not asked when the patient health record archive was designed
(Keränen, N., *Helsingin Sanomat newspaper*, 19/12/2010)

Figure 1. Titles of recently published news paper articles concerning IT system use in healthcare work.

Keeping with this pattern, all widely used Finnish EHR systems need immediate improvements to support healthcare professionals in their daily work with patients (Lääveri et al., 2008; Winblad et al., 2010). Observations indicate that the adoption of information systems has in several ways influenced clinical work practices. Physicians have argued that technology adaptation has dramatically increased the time dedicated for clinical documentation and supportive tasks (Lindqvist, 2008; Muuronen, 2008; Lindberg, 2008; Kaarto, 2008; Strann 2007). Patients have noticed that healthcare workers concentrate to a greater degree on working with computers during doctor appointments rather than building healthcare practitioner-patient relationships through communication (e.g. Karismo, 2008). Furthermore, newspaper columns have noted the rising concern with respect to reliability and patient safety issues as they relate to currently used systems and care delivery (Strann, 2008; Vuorenmaa and Kontio, 2008). Several academic studies concur with these findings. One of the main concerns with EHR adoption seems to be the ease of use and the amount of time taken up by clinical documentation and record-keeping (e.g. McDonald, 1997; Spies et al., 2004; Poissant et al., 2005; Häyrinen et al., 2008).

The consequence of healthcare IT adoption seems to be that the systems divert clinicians' attention away from their patients, and force them to spend more time on administrative work. Based on these findings, it is relevant to ask: What have we really gained with these remarkable investments in healthcare IT development? And why has this work so far led to failure with respect to the primary goals−streamlining workflow and making patient care more efficient?

The word 'failure' may seem like an exaggeration. However, it is not. In his summative article 'Health information systems: Failure, success and improvisation' professor Heeks (2006) has used the expression to illustrate the current state and challenges. Heeks argues that the best current estimation would be that healthcare IT failure is an important problem and suggests a design-reality gap model be used to address the problems both as a post hoc evaluation tool and as a pre hoc risk assessment and mitigation tool.

1.3 Problem Description: Mismatch between Information Systems and Clinical Work

User-centred design (UCD) has been applied broadly in various areas of software and service development. Since the introduction of usability in the late 1980s and the growth of usability testing during the 1990s, UCD has been understood as an approach to interactive system development that focuses specifically on making systems usable and incorporates a design process with four activities: 1) to understand and specify the context of use, 2) to specify the user requirements, 3) to produce design solutions, and 4) to evaluate designs against requirements (ISO 9241-210, 2010). Especially among global companies, understanding of end-user needs and expectations is seen as a prerequisite for developing solutions for demanding consumers.

Research conducted in the field of healthcare IT development in recent decades has mainly concentrated on technical issues. While many technical problems still remain unsolved (e.g., Kuhn and Giuse, 2001; Braller, 2005; Gides and Rivera, 2008), there seems to be a growing interest towards a people-oriented (or, to put it another way, a user-oriented) perspective. Since the early 2000s researchers have pointed out the need for research of user perspectives (e.g., Berg et al., 1998; Kuhn and Giuse, 2001; Poissant et al., 2005; Shah and Robinson, 2006; Karsh et al., 2010), usability studies (e.g., Zhang, 2005; Chaudhry et al., 2006; Gruchmann and Borgent, 2007; Glasgow, 2007; Paulus et al.,

2008), and methodology considerations (e.g., Zhang, 2005; Häkkinen and Korpela, 2007; Kushniruk, 2001; Kushniruk and Patel, 2004; Edwards et al., 2008). Empirical studies have applied traditional usability evaluation methods, particularly usability testing and inspections, to assess and measure clinical IT system usability.

It seems that researchers and practitioners in the healthcare domain share the aim of developing systems with high usability; however, it also seems that the approaches and procedures through which this development should take place are narrowly understood. User-oriented research in the field emphasises the evaluation approach. As stated by Ammenwerth et al. (2004):

> *Health information systems are intended to improve the functioning of health professionals and organizations in managing health and delivering health care. Given the significance of this type of intervention, and the intended beneficial effect on patients and professionals, it is morally imperative to ensure that the optimum results are achieved and any unanticipated outcomes identified. The necessary process is evaluation and this should be considered an essential adjunct to design and implementation of health information systems.*

In general, empirical usability studies are heavily affected by the traditional approaches to evaluation of human-computer interaction. These studies tend to share the following two characteristics in common (e.g. Peute et al., 2008): they focus on a single healthcare information system already in use and apply user testing or usability inspection methods. Therefore, little systematic data has been gathered to approach usability issues from a broader perspective and to support user-centred design of healthcare ICT systems, e.g.

a. examine usability in the context of clinical work, during which numerous systems are in use,
b. understand and describe the effects of system usability on professionals' working practices and daily work, and
c. study users' needs and expectations towards system development.

In health informatics literature, the definition for usability presented by the ISO standard (ISO 9241-11, 1998) is often referred to; however, no specific clarification or definition has been presented on the concept of the usability with regard to healthcare ICT or clinical IT systems. There are several examples. The Healthcare Information Management and Systems Society (HIMSS) report (by Belden et al., 2009) describes nine principles of EHR user interface design with reference to the ISO standard (ISO 9241-11) and emphasises efficiency, effectiveness, safety, user satisfaction and cognitive workload attributes. A consultative report by Schumacher et al. (2009) refers to the ISO stating that the usability goals for an EHR system must be set by specifying target values for effectiveness, efficiency, and satisfaction. In their paper on the contextual nature of usability, Svanæs et al. (2008) illustrate the context of use in healthcare settings with the help of three case descriptions, and highlight the importance of considering the contextual nature of usability.

More research is needed to promote the understanding of UCD, which will in turn build support of the research and development of healthcare IT systems. From the perspective of UCD, evaluation is only one of the four activities in the development process. In addition, the recently launched ISO 9241-210 standard (2010) emphasises the need for broadening the scope of usability and understanding usability as a contextual property – meaning that the objectives of usability studies should reflect the characteristics of the contexts of use for the interactive systems. The standard also describes the objectives of designing systems for usability as follows:

Usable systems can provide a number of benefits, including improved productivity, enhanced user well-being, avoidance of stress, increased accessibility and reduced risk of harm. (ISO 9241-210, 2010)

When reflected on in the domain of health informatics, the following questions can be raised to address the success of IT development and adaptation from the perspectives of end users, particularly clinicians: Do healthcare IT systems support clinicians in operative work? Are professionals able to conduct their work in an efficient and satisfactory way using these systems?

1.4 Focus of the Research

The contradictory results concerning the benefits of healthcare IT in clinical work, the current debate about healthcare ICT systems' usability, and the established need for a more systematic, user-centred approach to design and development motivated the development of this thesis and research.

In the health informatics field, the need exists for extension of the traditional approach to usability work, which concentrates on the evaluation of user-interface aspects, and on the interaction between a single user and a single interactive system. From the viewpoint of clinicians, research on the usability of a single system can be claimed as contradictory, perhaps irrelevant, when their daily work environment and the nature of their jobs are taken into account. In the clinical context, the technology environment consists of many IT applications, of which several are used simultaneously. With the end-users' perspective in mind, the research should address the usability of healthcare information systems from a broader viewpoint. Applications should be considered as integrated parts of a wider technology environment, and the objectives of usability considerations should be framed with respect to the end-user's daily tasks. This research is made even more challenging by the wide variety of users of EHR and other IT applications, the numerous purposes these programmes serve, and the diversity of clinical surroundings at healthcare organisations in which the applications are implemented and used.

The domain of the research in this thesis is a combination of *health informatics* and *user-centred design (UCD)*. The thesis explores the evolving area of healthcare ICT development from the perspective of UCD in the context of *clinical work*. The author's background is in the field of UCD research. The thesis work draws from human-computer interaction (HCI) research (Nielsen, 1993; Dix et al., 2003; Sears and Jacko, 2008), applies a UCD approach and methods in research, and builds on earlier studies on usability of healthcare technologies (e.g. Kushniruk et al., 2005; Kjeldskov et al., 2007; Edwards et al., 2008).

Although the discipline of health informatics is young, many research areas have already gained wide acceptance and are attracting the interest of research groups working in the field. In recent years, several conferences (e.g., HIMSS[3], ITCH[4], MIE[5], AMIA[6]and e-

[3] Healthcare Information and Management Systems Society, website: http://www.himss.org

[4] An international conference addressing Information Technology and Communication in Health (ITCH), www-pages: http://itch.uvic.ca/index.php.

Health[7]) have, among other themes, appreciated the implications of human-computer interaction and usability considerations. For example, at the MIE 2011 conference[8] one of the main topics was usability:

- Of all the 195 full papers accepted, 45 dealt with usability-related topics.
- The first keynote speech of the conference, given by Marie-Cathrine Beuscart-Zephir, the founder of Evalab at Lille University, was titled "Human Factors and Usability for Complex Health Information Technologies: Why do You Care?".
- As indicated in the conference program, numerous parallel sessions were held under the title "Usability, HCI, and cognitive issues".

Likewise, topics related to healthcare and well-being are increasingly appearing at conferences in the fields of human-computer interaction (HCI) and computer-supported cooperative work (CSCW). These observations indicate that the area of usability-oriented research of healthcare ICT systems seem to be in the process of establishing an identity in both research fields – among researchers working in the fields of HCI and health informatics. Furthermore, this growing interest indicates that research on healthcare ICT systems usability can a) be seen to have novelty value and b) have the ability to result in new scientific knowledge.

Health informatics. Health informatics, often referred to as *medical informatics*, is a combination of computer science, information science, and health science, and has a number of sub-domains, including among others clinical informatics, telemedicine, consumer health informatics, and healthcare management informatics (Coeira, 2003; Conrick, 2005; IMIA website; AMIA website). The scope of health informatics is thus wide and multidisciplinary.

The discipline of health informatics deals with the collection, storage, retrieval, communication, and optimal use of health-related data, information, and knowledge (HISA website). The primary focus of research has been on healthcare information systems, which are typically associated with computer systems in hospitals that include functions for patient admission and discharge, order entry for laboratory tests or medications, and billing (Coeira, 2003). These systems include EHR systems, clinical decision support systems, computerised provider order entry, and picture archiving and communications systems (Hackbart et al., 2004).

In the literature, several concepts are used to describe technology applications that support care and nursing activities. In this thesis, *clinical IT systems* are used to refer to those information systems that clinicians use in their daily work with patients,

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[5] International Conference of the European Federation for Medical Informatics, conference website: http://www.mie2011.org/.

[6] American Medical Informatics Association (AMIA) Annual Sumposium is the world's most comprehensive annual meeting on biomedical and health informatics. Symposium website: http://www.amia.org/amia2011.

[7] eHealth conference website: http://www.e-healthconference.com/.

[8] XXIII International Conference of the European Federation for Medical Informatics with about 650 participants, conference website: http://www.mie2011.org/index.htm.

particularly EHRs and nursing documentation systems (NDSs). On the other hand, clinical information and communication technology (*clinical ICT*) is used to cover a broad array of technologies that enable clinicians to conduct various care-related activities and to communicate and interact with distant services and stakeholders (e.g. patients) without the limitations of time and space.

User-centred design (UCD) and usability. In the academic world, UCD is associated with human-computer interaction and usability research. Closely related research approaches include, to mention but a few, human factors or ergonomics, participatory design, and scenario-based design. The research domain also shares several interests with CSCW, as well as research on technology acceptance and information system success.

UCD is an approach to interactive system design and development that focuses specifically on making systems usable (ISO 13407, 1999). Generally speaking, the objective of designing systems for usability can be described as to enable the users to achieve the goals and meet their needs in a particular context of use (ISO 9241-11, 1996; ISO 9241-210, 2010).

In practice, the scope of a UCD approach can vary substantially. In this thesis, UCD is seen to cover the broad end of the spectrum. The UCD approach provides the basis for a methodology that emphasises the development of interactive systems with high usability. The approach also guides the research on interactive systems in use for the purposes of further development. The approach includes

- four activities of human-centred design;
- the process model of interactive system design;
- the principles of UCD (e.g. users are involved throughout design and development and an iterative process) as described in the ISO 9241-210 standard (2010); and
- from the viewpoint of methodology, a wide range of qualitative but also quantitative methods introduced and applied in UCD and related research fields.

Furthermore, the term *UCD methods* specifically refers to those established practical means for conducting user research, gathering of requirements, design, and evaluation activities during the process of interactive system development.

The following paragraphs are to clarify the meanings of the concepts of *UCD* and *usability* and the relationship between these, and thereby describe what UCD means in the context of this thesis.

Several conceptualizations and definitions of the notion *usability* have been presented in the human-computer interaction (HCI) research field (e.g. by Nielsen, 1993; Shackel and Richardson, 1991; Shneiderman, 1987; Bevan, 1995). Most of these describe usability as being a contextual property, meaning that usability should always be defined and measured in relation to specific settings. Probably the most often cited definition of usability is by the ISO standard (ISO 9241-11, 1996): *Usability is the extent to which a system can be used by specific users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use*. The other also widely known definition is presented by Nielsen (1993), who states that the two most important issues for usability are the users' tasks and their individual characteristics and differences. Figure 2 illustrates the components of usability and the relationship between them as described by the ISO standard and Nielsen.

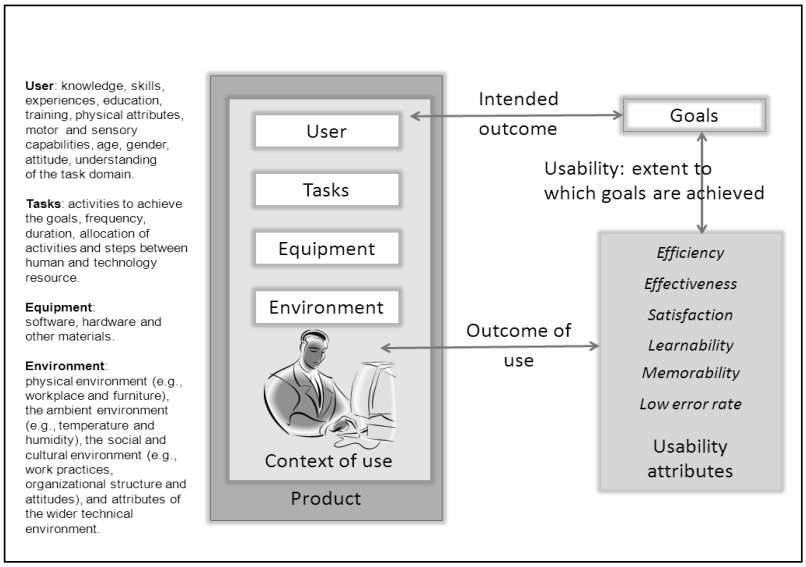


Figure 2. The components of usability (ISO 9241-11, 1996; Nielsen, 1993).

The definitions of usability by both ISO 9241-11 and Nielsen emphasize the relation between usability and context of use; the level of usability achieved will always depend on the specific circumstances in which a product is used. These specific circumstances can be described as the elements of context of use: users, tasks, equipment, and the physical and social environments in which a product is used or is intended to be used (ISO 9241-11, 1996).

Traditionally, usability is associated with interaction between a human and a computer system, whereas user experience (UX) has emerged as a new concept that emphasises the emotional aspects resulting from the use of a system. The recently launched ISO 9241-210 (2010) standard clarifies the relationship between concepts of usability and UX by stating that UX refers to a person's perceptions and responses resulting from the use and/or anticipated use of a system. Accordingly, usability should be understood as a broad concept that includes the kind of perceptual and emotional aspects typically associated with user experience. Furthermore, Hertzum (2010) has, in his recently published article, argued on behalf of extending the scope of practical usability work and introduced multiple images of usability: universal usability, perceived usability, hedonic usability, organizational usability, and cultural usability. Of these, "situational usability" defines usability as an attribute of the interaction between systems, user, task, and contextual conditions. "Perceived usability", on the other hand, suggests that the usability of a system is experienced by its users and is paramount to whether the systems get adopted, used, and liked or rejected.

Seeing that the conceptualizations for usability emphasise various viewpoints and cover issues ranging from emotional and temporal dimensions to user's goals and collaborative aspects of work, one can realise that usability is not only a characteristic of a user interface. Instead, usability should be understood as a multi-dimensional property, highly dependent on the context of use.

There is a substantial body of usability and human factor (or ergonomics) knowledge concerning how UCD can be organised and used effectively. The already discussed key concepts of UCD, usability, and context of use offer some guidance for user-oriented

design and the evaluation of interactive systems. However, it is the ISO 9241-210 standard (2010) titled "Human-centred Design for Interactive Systems" that provides guidance in designing systems with high usability. In accordance with Gould and Lewis (1985) and Gulliksen et al. (2003), the standard describes six principles that characterize UCD:

1. The design of interactive systems is based upon an explicit understanding of users, tasks, and environments
2. Users are involved throughout the design and development
3. Design is driven and refined by user-centred evaluation
4. The process is iterative
5. The design addresses the whole user experience
6. A multidisciplinary design team.

These principles indicate that the planning for usability, as part of the design and development of systems, involves the systematic identification of requirements and verifiable descriptions of the context of use. Accordingly, the four UCD activities to be fitted into the overall development process are 1) understand and specify the context of use, 2) specify the user requirements, 3) produce design solutions, and 4) evaluate the designs. These phases should be repeated iteratively until the system meets the requirements. (ISO 9241-210, 2010)

Generally speaking, the ISO 9241-210 standard and included principles are intended to provide general guidance for the planning and management of UCD, not to incorporate detailed coverage of the methods and techniques. The range of existing methods for practitioners of UCD is extensive and varies from ethnographic and field study methods to measurements of efficiency and techniques (such as the 'wizard of Oz' technique) for creating interactive prototypes (e.g. Hackos and Redish, 1998; Usability Body of Knowledge website; Usability Net website). The principles of UCD are not bound to any specific phase of development cycle, but instead can be integrated into different stages of the design process in a way that is appropriate for the particular context. The earlier published standards on usability, particularly ISO 9241-11 (1998) and ISO 13407 (1999), specifically apply to computer-based systems in office work. However, the recently launched ISO 9241-210 deals with computer-based interactive systems of larger scale, including off-the-shelf software products, custom office systems, web sites and applications, and mobile phones (ISO 9241-210, 2010).

Context of clinical work. The context of the empirical studies detailed in the thesis is clinical work and its surrounding environment. By definition, *context of use* describes the circumstances in which a specific system, product, or service is used, and includes four components: user, systems, tasks, and environment (ISO 9241-11, 1998). The following components of clinical contexts describe the scope of the research.

- *Users*: Physicians and nurses.
- *Systems:* ICT systems used in clinical work, particularly large-scale information systems such as electronic health record (EHR) systems and nursing documentation systems (NDSs).
- *Tasks:* ICT-supported patient care and nursing activities, e.g. documentation and information retrieval, decision making, and communication between healthcare professionals.
- *Environment:* The clinical working environment, including technological, social, and organisational aspects as well as the wide variety of healthcare surroundings (e.g. healthcare centres, hospitals, as well as wards and clinics) with a number of medical fields of specialisation.

2 DEVELOPMENT OF HEALTHCARE INFORMATION SYSTEMS: CLINICIAN'S PERSPECTIVE

According to Davis (1973), healthcare information systems are primarily about the timely delivery of relevant, needed information to the appropriate healthcare professional. This section gives an overview of healthcare technology development through a focused literature review, with an emphasis on clinical IT system development and clinicians' perspectives.

2.1 Past

The history of healthcare information system development begins about 50 years ago, as experiments with computerised medical record keeping began in the 1960s. At the same time, the concept *health informatics* seemed to find a permanent position amongst academic interest groups (Wilson et al., 2004). By the middle of the 1970s, computers were widely used in hospitals (Goldschmidt, 2005), as the benefits of using information technology to manage the complex and diverse work environment of hospitals became evident.

In the 1980s healthcare organisations followed the introduction of personal computers, and physicians began adopting electronic health record systems (Goldschmidt, 2005). Since then, various healthcare-tailored applications for diverse practice settings and physician specialties have been developed to serve the needs of the profession. However, at the first appearance of these stand-alone applications it soon became clear that they poorly supported patient data exchange between hospital units and healthcare parties. The quest for integrated records that could follow the patient through the healthcare delivery system was announced.

In the late 1990s, EHR systems were identified as 'essential' (Dick et al., 1997) and 'at the heart of the application of IT in healthcare' (Grimson et al., 2000). Today, the range of EHR systems already in place is described as being huge (Wilson et al., 2004). In the literature, the concept of 'electronic health records' covers a wide range of different information systems, from files compiled in single departments to longitudinal collections of patient data (Häyrinen et al., 2008). Healthcare professionals use these records as their principal information repository for the purpose of setting objectives, planning patient care, documenting the delivery of care, and assessing the outcomes of care (e.g., Häyrinen et al., 2008).

2.2 Present and Future

In the 21st century, information technology in healthcare organisations has gained widespread usage. In recent decades, many European countries have adopted EHR systems with the aim of replacing existing paper-based patient records with EHR systems that enable better integration, sharing of information, and smoother collaboration amongst different healthcare providers. While national health record systems are still less common (World Health Organisation, 2008), various kinds of department-wide and organisation-wide systems have now been in use for many years. Additionally, nation-wide healthcare

information infrastructure projects and strategies are under development in many countries (World Health Organisation, 2008).

From the early 2000s, the ideology of patient-centred care has slowly entered the field and started to influence healthcare ICT development. The visions (e.g., by Davis et al., 2004; Delbanco et al., 2001; Haux et al., 2002) share the idea that technology has an important role in supporting patient-centred care, including in: a) information delivery and communication between clinicians and patients and other involved parties (e.g., family and social workers), b) coordination of care, and c) cooperative care. These changes suggest that healthcare technologies should evolve in the direction of providing a greater degree of open access to patient information and records. As a consequence, the concept of a patient health record (PHR) system has been launched with the following understood meaning:

> *PHR systems are more than just static repositories for patient data; they combine data, knowledge, and software tools, which help patients to become active participants in their own care. When PHR systems are integrated with EHR systems, they provide greater benefits than would stand-alone systems for customers.* (Tang et al., 2006)

The core functionalities of PHRs are said to include the ability to share test results and medication information, while the more specialised PHRs include functions like electronic appointment scheduling, e-visits, and interacting via e-mail with the doctor (Dimick, 2008; Wiesenthal, 2009). Furthermore, the PHR-enabled communication can provide healthcare professionals with greater flexibility in working procedures and free up resources to improve the efficiency of personal communications between physicians and patients (Tang et al., 2006; Wiesenthal, 2009).

The concept that patients and citizens should take a more active role in their own care has been strongly encouraged and appreciated. *e-Health*, and more recently *m-Health* (mobile health), are the terms behind these concepts, and describe the merging ICT-supported practices and activities in health care. Most interested parties conceptualise e-Health as a broad range of healthcare technology applications that facilitate the management and delivery of healthcare. According to Mitchell (1999), e-Health describes the combined use of electronic communication and information technology in the healthcare sector for clinical, educational, and administrative purposes, both on-site (i.e., at the clinical or hospital) and remotely. From the viewpoint of healthcare workers, e-Health is thought to cover complex clinical applications that can support clinicians in diagnosis and treatment (Wilson et al., 2004).

Along with e-Health, the involvement of citizens in healthcare is now policy in many countries (Health Committee, 2007; Ruotsalainen et al., 2008). The future scenarios describing healthcare by the year 2013 suggest that consumers will assume much greater financial oversight and responsibility for their healthcare, which in turn will drive the demand for value data that is readily accessible, reliable, and understandable (Adams et al., 2006).

The development of healthcare information systems to date has concentrated on computer-based applications, without paying much attention to other areas of modern technology. However, interest in the adoption of wireless and mobile technologies inside hospitals has increased remarkably in recent years, as was illustrated by summative reports on recent survey results for smartphone trends by Amcon Software (2011) and by Dolan (2011). For example, a recent survey in United States found that 64 percent of physicians have a smartphone, while 27 percent of primary care providers and specialists say they have a tablet (Dolan, 2011). Based on the results, it remains unclear how widely

these are used in clinical settings, since very few healthcare providers appear to have officially announced mobile healthcare pilots (Dolan, 2011).

Currently, several healthcare IT companies are developing portable and mobile applications for clinical use—it seems that possibilities finally exist for overcoming technical challenges that have stymied the use of existing technologies for healthcare purposes for decades. With regards to these mobile solutions, software companies apparently realise the necessity of understanding the contextual issues behind use of the technologies: for example, when the size of the screen is smaller it becomes increasingly important to offer the user the most important information, and implement only a selected set of functionalities (e.g., see presentations by Ehlting (2011) and Schall (2011) at the Connecting Healthcare IT (ConhIT) Congress, and by Lohmann (2011) from Lohmann & Birkner Health Care Consulting company). Inside the hospitals, however, the overall situation with regard to information system usage has not changed much. As an example, in Germany some units are currently pilot-testing the use of laptop trolleys (with wireless network connection and touch screen functionality) during ward rounds (presentation by Schall, 2011), and testing iPads as a new kind of interface to numerous sources of patient information (Lohmann, 2011).

2.3 Promises and Challenges

From the clinician's perspective, promises and possibilities underlying healthcare IT adaptation in clinical contexts are described to be manifold, including reduced time with record keeping and improved workflows; automated sharing of information among providers and patients; direct access and instant updates to records; more accurate and better-structured clinical data and documentation; automatic sorting and summarisation of data; fewer dangerous medical mistakes; and continuous improvement in clinical decision making (Goldschmidt, 2005).

However, the development and adaptation of IT applications in healthcare has proved to be challenging. Most of the challenges reported are still related to technical aspects; on the other hand, issues related to user friendliness are also becoming more important. The commonly referred-to challenges that emphasise the end-user's perspectives include:

- *Lack of interoperability and integration of separate systems* (e.g. Braller, 2005; Chaudhry et al., 2006; Khoumbati and Themistocleous 2006; The Joint Commission, 2008). According to Braller (2005), interoperability is a fundamental requirement for the healthcare system to derive the benefits promised by the adoption of EHRs.
- *Failures in implementation* (e.g. Berg, 2001; Lenz et al., 2007; Thielst et al., 2008). Berg (2001) has described the three myths that often make the implementation process difficult as follows: (1) during the development process both the organisation and the technology transform each other, (2) a process requires proper support by both central management and future users, (3) the appropriate management actions should concentrate on balancing initial organisational change and information system-oriented change.
- *Lack of user involvement and considerations related to the 'human factor'* (e.g. Zhang, 2005; Tang et al., 2006; Gruchmann and Borgert, 2007; Weng et al., 2007). Many researchers have strongly emphasised that the healthcare information system should be understood as a complex sociotechnical system. Therefore, software development should be based on an understanding of a variety of user groups and their needs, and the dynamic context of healthcare work (Tang et al., 2006; Häkkinen and Korpela, 2007; Häyrinen et al., 2008).

- *Shortage of expertise on participatory design practices and user-centred development methods.* Several researchers (e.g. Fairbanks and Caplan, 2004; Tang et al., 2006; Häkkinen and Korpela, 2007; Hersh and Wright, 2008; Martikainen et al., 2010) have emphasised the need for understanding the contextual aspects behind system design and involving end-users in development activities.

Of all the healthcare information systems, several problems seem to be particularly related to the use and adoption of EHR systems. From the beginning, these systems have been developed to support documentation and information delivery between healthcare professionals and thereby improve the safety and quality of care. By the late 1990s, researchers had already argued that the failure to view the hospital as a system had contributed to the practise of inefficient and ineffective clinical documentation (Healthfield et al., 1998). In his article 'Barriers to EHRs and how to overcome them' McDonald (1997) identified two challenges that must be solved to optimise medical record keeping in the context of EHR: 1) the capture of physician-gathered information must be efficient, and 2) a minimum but affordable set of variables needed to be identified for the purpose of assessing quality and outcomes of care.

In the 21st century, several studies have emphasised the need for a good fit between the EHR system and routine clinical practices (e.g. Poissant et al., 2005; van der Meijden et al., 2003; Pizziferri et al., 2005; Spies et al., 2004). However, these clinical practices are not easily defined, for the reason that EHRs are used by many different healthcare professionals. As pointed out by Häyrinen et al. (2008), the needs and requirements of all users of EHRs should be accounted for during development of an EHR system. Their literature review indicated that nurses and physicians currently on the wards typically record patient data in their own separate information systems. Due to this, it is difficult to use the documentation/records of another nurse or physician, which may adversely affect patient care. In conclusion, the development of EHRs to serve healthcare workers in their operative work environment, and during their care of patients, remains a work in progress and a fundamental challenge for healthcare IT development.

3 USABILITY-RELATED RESEARCH IN THE HEALTH INFORMATICS FIELD

User-oriented evaluation studies in the field have tended to focus on IT adaptation and user satisfaction issues. Typically, studies on user satisfaction have investigated users' opinions or attitudes on a rather general level, not in the context of usability research. Since the early 2000s, however, interest in usability issues has grown. This chapter describes an overview of usability-related studies in the health informatics field based on literature available in the fields of health informatics and human-computer interaction. Literature review was conducted in a way that the author searched through several relevant research and publication forums and ended up including 93 publications.

The literature review attempts to answer the following questions:

- What types of studies have been conducted?
- What is currently known about UCD in the health informatics field?

This overview begins by firmly establishing the need for the development of a user-based approach to healthcare IT development.

3.1 Established Need for a User-oriented Approach

Why bother considering users in healthcare IT development? Researchers working in the health informatics have suggested the following reasons:

> *The starting point for development should be through insight into the healthcare work practices where the information systems are to be used.* (Nykänen and Karimaa, 2006)
>
> *Only a system that reflects the professionals' working practices will encounter their acceptance.* (Reuss et al., 2007a)
>
> *Factors of usability and ergonomics are of key importance for the adoption of medical information system solutions in practice.* (Weber-Jahnke and Price, 2007)
>
> *In order to avoid the currently faced dissatisfaction and abandonment, significant attention should be paid to user-centred design guidelines during healthcare information system development.* (Johnson et al., 2005)
>
> *The design of successful user interfaces poses one of the most important challenges in the area of health informatics.* (Patel and Kushniruk, 1998)
>
> *Commitment to usability in medical product design and development offers enormous benefits, including greater user productivity, more comprehensive products, lower support costs, and more efficient development process.* (Gruchmann and Borgent, 2007)

Based on these comments, the need for user involvement seems to be clearly established. However, several researchers in health informatics field have highlighted the need for a more systematic approach on user perspectives throughout the development process. Among others, Zhang (2005) has expressed his concern about and experiences with the current state of user considerations in healthcare technology development as follow:

In healthcare the culture is still to train people to adapt to poorly designed technology, rather than to design technology to fit people's characteristics.

This claim has been supported by several researchers. De Rouck et al. (2008) argued that healthcare users still lag behind in participation in the development of technologies. Gruchmann and Borgert (2007) have suggested that the integration of a usability approach is not easy, nor a straightforward process, but requires the involvement of specialists trained in and experienced with accounting for the human factor. Chaudhry et al. (2006) have pointed out the need for additional studies in workflow redesign and human factors to fully realise the benefits of IT use. Among others, Gil-Rodríguez et al. (2007) argue that the study of organisational, contextual, and user variables affecting implementation of technological innovations is vital to guarantee that those innovations respond to existing problems in the healthcare system. Similarly, Paavola (2008) has concluded that the success in IT projects often requires knowledge not only of the technology—the applications, hardware and architecture—but also of the users, the procedures, and the business.

3.2 Studies on User Satisfaction and Technology Acceptance

A wide variety of approaches and methodologies have been applied in assessing the impact of information systems in clinical settings, ranging from controlled clinical trials to the use of questionnaires and interviews with users. In particular, the *questionnaire technique* has been used to address a wide range usage issues related to healthcare IT, the most typical of these being user satisfaction, attitudes, and experiences of use.

In Norway, research conducted in the form of a longitudinal survey was applied to the investigation of general practitioners' *use of EHRs*, with emphasis on the systems' ability to support clinical tasks and inclusion of aspects related to user satisfaction and perceived usefulness of the technology (Christensen et al., 2009). A Similar national questionnaire study with Irish general practitioners was conducted in 2000 and again in 2003 to determine factors that were affecting the uptake of an EHR system (Meade et al., 2009). A Study by Davis et al. (2009) is one of the few EHR studies reporting results from an international survey with primary care physicians. The study focused on the relationship between IT functional capacity and the physicians' perception of and satisfaction with the care they provide. Other studies have dealt with EHR use and user satisfaction in various contexts: in an emergency department (Likourezos, 2004), during ambulatory visits (Linder et al., 2006), at the offices of family physicians (Edsall and Adler, 2005), and in the Finnish primary healthcare system (Mäkelä et al., 2010). Some recent studies have also specifically explored nurses' perceptions and degree of adoption of patient information systems (Oroviogoicoechea and Watson, 2009; Lee et al., 2008).

Questionnaire studies have also addressed the physicians' attitudes towards and opinions about the usefulness of speech technology (Alapetite et al., 2009), the Internet and online evidence system for information retrieval (Jacko et al., 2001; Gosling et al., 2004), provider order entry and decision support systems (Rosenbloom et al., 2004; Ruland, 2004), and health information exchange (Patel et al., 2011). In contrast to these studies, which each covered one very specific aspect of healthcare IT adoption, studies of the acceptance of healthcare IT applications have covered a wide spectrum of topics related to this acceptance (e.g. Yu and Gagnon, 2009).

The previously described questionnaire studies have provided important information about healthcare technology usage from various perspectives. In general, EHRs are in widespread use among physicians in several countries (e.g. Christensen et al., 2009;

Meade et al., 2009) and longitudinal studies have indicated that the frequency of EHR use is generally increasing (Christensen et al., 2009; Meade et al., 2009, Lærum et al., 2001).

However, in spite of the increasing frequency of EHR use, the questionnaire studies have revealed that physicians have mixed attitudes and experiences concerning them. A recent survey of over 10,000 respondents from medical offices in the United States pointed out serious challenges to the appropriate use of patient charts (medical records): 86% of respondents agreed that an incorrect chart had been used for a patient during the past 12 months; 63% indicated that a patient's chart was not available when needed; and 44% stated that a patient's medication list was not updated during the visit (Agency for Healthcare Research and Quality, 2010). Study by Edsall and Adler (2005) indicated high user satisfaction towards EHR functionality. Oroviogoicoechea and Watson found the nurses' viewed healthcare information systems positively on the whole (Oroviogoicoechea and Watson, 2009), whereas Lee et al. (2008) found slightly negative ratings for healthcare information systems. Likewise, in a study conducted by Likourezos et al. (2004), clinicians suggested that EHRs have a positive effect on their work, but not on patient care. Results for this study also indicated differences (or, perhaps more accurately, contradictory experiences) with physician experiences regarding speech recognition in voice dictation systems. Physicians argued that the time taken producing medical records had increased, but at the same time the new technology had satisfactorily led to improvements in workflow.

The body of literature (that is, questionnaire studies) on health information systems indicates that the following elements are the most significant barriers to adoption and use of healthcare information systems: concerns with the amount of time it takes to use the system (Meade et al., 2009; Likourezos et al., 2004; Linder et al., 2006), efficiency (Linder et al., 2006; Lee et al. 2008), user support (Lee et al., 2008; Gosling et al., 2004), system functionality (Gosling et al., 2004), confidentiality of patient information (Likourezos et al., 2004), and dehumanisation of patient contact (Linder et al., 2006). The success factors for healthcare information system, therefore, would be the reverse of some of these challenges: ease of use; no increase in workload; and timely, precise information (Ruland, 2004). Positive experiences deriving from the introduction of computerised physician order entry (CPOE) included improvements in quality of care, support for providing quality patient care, and improved efficiency of order entry (Rosenbloom et al., 2004). The results of EHR use, management, and potential problems in Finnish primary healthcare showed that large differences exist in working practices and in the way EHR systems are managed and utilised (Mäkelä et al., 2010). The study also demonstrated the need to improve and broaden the use of EHR systems and increase emphasis on IT management, support, training, and best practices dissemination.

3.3 Evaluation Studies

The significance of evaluation studies has grown during the past decade in the health informatics field as a consequence of IT adoption and use-related problems and contradictory findings. For a substantial period of time, evaluation studies were dominated by quantitative measurements (such as time measurements, user acceptance measurements, length of stay measurements, and error rate scores) (Ammenwerth and de Keizer, 2005). Interestingly, the nature of evaluation seems to be slowly changing—qualitative methods and research approaches are slowly entering the field in tandem with increased interest in adequate methods and approaches for evaluation (Ammenwerth and de Keizer, 2005).

Review of the literature indicates that usability tests and inspection methods, together with interviews and questionnaire surveys, are currently the most commonly used

methods for capturing user perspectives (Shah and Robinson, 2006; Peute et al., 2008). Reviews have also pointed out that users tend to be involved mainly during the later phases of the healthcare technology lifecycle, in the testing and trial stages of development.

Recently, several papers have focused on methodology aspects and described how to evaluate healthcare information systems. These include approaches and methodologies such as:

- Establishment of guidelines for good evaluation practices in health informatics (Nykänen et al., 2009; Nykänen et al., 2011b), guidance on employing these when planning to test success (Rigby et al., 2009), and statements on reporting evaluation studies (Talmon et al., 2009).
- Introduction of formative versus summative evaluation methods (Belden et al., 2009).
- Cognitive and usability engineering methods (e.g. Beuscart-Zéphir et al., 1997; Kushniruk and Patel, 2004; Jaspers, 2009; Janß et al., 2007; Horsky et al., 2003) and variations of cognitive analysis (e.g. Hall et al., 2011; Kushniruk et al., 2011).
- New methodologic approaches to user-oriented evaluation, including remote testing (Bastien, 2010), cooperative usability testing (Følstad and Hornbæk, 2010), simulations (Kushniruk et al., 2008; Borycki and Kushniruk, 2010), qualitative usability testing enhanced with data-mining techniques (González et al., 2008), and evaluation of mobile applications (Bastien, 2010; Alsos and Dahl, 2008).
- Human-computer interaction originated frameworks for evaluating new interactions in healthcare. Examples of this include a framework by Favela et al. (2010) that can be used by researchers to select appropriate techniques as a function of technological and environmental complexity; a framework by Dahl et al. (2010) to guide designers as they design healthcare simulations for evaluation purposes; and a framework by Tang et al. (2010) to guide the collection and analysis of data for in situ evaluations.
- In situ evaluations instead of conventional usability testing (e.g. Wilson et al. 2007).

A considerable number of usability evaluation studies in the field have concentrated on the later phases of IT development, and evaluated systems that are already in use. Typically, usability evaluation studies have focused on clinical IT systems, particularly EHR systems (e.g. Kjeldskov et al. 2008; Edwards et al., 2008). However, examples of other kinds of studies can be found also. Kushniruk et al. (2005) evaluated the usability of a handheld prescription-writing application; other evaluated systems include a system for computer-supported ordering of laboratory tests (Peute and Jaspers, 2007) and a tele-nursing call management software system (Hall et al., 2011).

Results from recent studies suggest that currently used healthcare information systems suffer from a high number of usability flaws that considerably hinder the use of computer systems. The evidence that supports this point of view is strong. Some systems demonstrated flaws that rendered them less-than-optimal for use include the following; these systems were all detailed in the literature:

- An EHR system with 103 flaws related to complexity of information, poor relationship to work activities, and lack of support for mobility (Kjeldskov et al., 2008).
- A Physician order entry system with 33 flaws related to user interface and user interaction issues (Peute and Jaspers, 2007).
- A handheld prescription writing application with 73 flaws related to interface design issues (Kushniruk et al., 2005).

- A commercial EHR system in a large paediatric hospital with 134 flaws related to consistency, user control, flexibility, efficiency, and natural dialogue (Edwards et al., 2008).
- A tele-nursing call management software with 100 discrete usability errors and problems (Hall et al., 2011).

In addition to enumerating problems, some researchers have suggested concrete ideas for improvements; however, little information is available to describe the effects of such actions, or the implications for further design and development.

In general, recent usability evaluation studies share several characteristics: they focus on a healthcare information system already in use, apply traditional evaluation methods (user testing, heuristic evaluation, or cognitive walkthrough) and typical testing procedures, are conducted in one specific context, and involve one end-user group perspective (healthcare professionals within the same area of expertise).

In addition to typical approaches on evaluation, a few researchers have used *usability questionnaires* to evaluate prototypes (Stoicu-Tivadar and Stoicu-Tivadar, 2006) and healthcare IT systems already in use for applications such as a hospital information system (Hamborg et al., 2004), a cardiology ward application and two laboratory applications (Terazzi et al., 1998), and a computer-assisted surgery system (Martinelli et al., 2003). These studies have utilised both tailored (Martinelli et al., 2003; Stoicu-Tivadar and Stoicu-Tivadar, 2006) and established usability questionnaires like IsoMetrics (Hamborg et al., 2004) and the Software Usability Measurement Inventory (or SUMI) (Terazzi et al., 1998). The following positive and negative usability findings (among other results) have been shown by these studies (Hamborg et al., 2004; Terazzi et al., 1998):

- *Positives*: Easy data entry, easy to use appropriate terminology and adjust data presentation;
- *Negatives*: The software necessitates additional tasks and interaction steps, with low intuitiveness to its design and low user satisfaction.

3.4 User Research and Participatory Design Studies

Although evaluation studies have dominated the research of usability issues in the clinical IT development field, some examples of *user research studies* and *participatory design studies* can be found as well. These studies have typically applied variations of observation and interview methodologies and of the participatory design approach.

The Study by Reuss et al. (2007a, 2007b) is one of the few that reports the daily work practices of physicians and nurses with the integration of use of information systems. In addition, some studies have focused on investigating the information needs of healthcare professionals to outline fundamentals for technology development and support the early phases of concept design (e.g. Häkkinen and Korpela, 2007; Weng et al., 2007; Kyhlbäck and Sutter, 2007; Elf et al., 2007; Gil-Rodríguez et al., 2007, Braun et al., 2007).

Findings from the field studies by Reuss and others (e.g., Kyhlbäck and Sutter, 2007; Braun et al., 2007) reflect the diversity of working practices and working contexts, and emphasise the need for good fit between healthcare systems and the users' needs and practices. For example, study results show that:

- Professionals' work is characterised with a number of interaction patterns (Reuss et al., 2007a).

- Recording information using clinical IT systems cannot be considered as a standardised process, since information recording practices can vary considerably (Reuss et al., 2007b).
- The role of worksheets in nurses' work is critical; nurses use worksheets to manage all relevant information during the entirety of their shifts (Reuss et al., 2007a).
- The work of nurses is different in its essence from the work of office workers and machine operators. Furthermore, work practices of the municipal nurses are characterised by three distinctive features: high mobility, the need for face-to-face interaction in different locations, and a great variety of artefact usage (Kyhlbäck and Sutter, 2007).
- Although a physician's information needs can be generalised, a number of identified needs are hardly manageable or even unmanageable (Braun et al., 2007).

Only a few examples of iterative development studies exist in which user-centred methods have been used to support design activities. A few researchers have reported *contextual inquiry studies*. Gennari and Reddy (2000) applied the participatory design approach and used contextual inquiry to design and build a protocol screening tool of clinical trial protocol management. Gil-Rodríguez et al. (2007) applied the method to collect information about cognitive, symbolic, and practical characteristics of IT systems use on daily tasks in clinical settings, with the aim of supporting the design of graphical user interfaces for telecardiology applications.

The reported experiences from *iterative development projects* using user-centred methods are highly encouraging. One example is the Gravi project (Pohl et al., 2007), which aimed at developing an application to help clinicians visualise information. The study incorporated three evaluation cycles, during which the application was redesigned and greatly improved. The researchers found that the application developed was very successful, and proposed that it could easily be used for other areas of application in the field of medicine. Likewise, Wilcox et al. (2010) reported positive outcomes and experiences based on their study, in which they employed a fieldwork approach (observations, interviews, and feedback gathering) when developing a clinical documentation prototype. Further, the developed severe pain management tool for palliative care was found to be ideal for its purposes (Kuziemsky et al., 2006). The researchers believed that the information system tool was to meet the medical, technical, and social needs of a palliative information system, and thereby help to address issues of context around problematic models of care.

Several studies have applied *participatory assessment* in the design of clinical IT systems (e.g., Kyhlbäck and Sutter, 2007; Waller et al., 2006; Karasti, 2001; McKay et al., 2001; Elf et al., 2007). Waller et al. (2006) developed a text message scheduling system that delivered automated text messaging support to young people with diabetes. Experiences with the project (and the participatory approach to development) were positive. From this project, the developed prototype was extended to facilitate support and communication. Additionally, the redesign of a telecardiology system appeared to be successful (Karasti, 2001). To support the design process, Karasti first arranged workshops to gather information about the work practices of radiologists. Potential users were actively involved in the design process. The advantages of a participatory design approach were seen as manifold: practitioners' active participation opened possibilities for design considerations and improved opportunities to avoid the presumed gap in actual design situations.

3.5 Methodology Considerations: Experiences, Challenges, and Suggested Approaches

Reported experiences and challenges with usability and other user-oriented methods are many. This section begins to approach the topic of what the best manner to obtain information concerning these challenges and experiences, taking into account the context of use of EHRs and healthcare ICT, and the perspectives of both physicians and patients.

Usability evaluation methods: According to Jaspers (2009), each usability evaluation method (heuristic evaluation, cognitive walkthrough, and 'think aloud' or usability testing) has its own disadvantages and advantages when applied in healthcare technology development. This is illustrated by Edwards et al. (2008) who stated that several challenges with heuristic walkthrough derived from the complex nature of the clinical work domain and limitations of the predictive evaluation method. Therefore, accurate reflecting of the realism and concreteness of healthcare contexts should be paid special attention (Svanæs et al., 2010), as should the evaluation of system usability in collaborative tasks (Edwards et al., 2008).

Experiences from practical studies have indicated that usability evaluation methods are time-consuming (Spies et al., 2004) and noted difficulties in integrating results into the iterative system development cycle (De Rouck et al., 2008). On the other hand, experiences on the use of *usability questionnaires* during the development cycles have shown generally positive findings about the user interface characteristics and helped the developers to improve the design (Martinelli et al., 2003; Stoicu-Tivadar and Stoicu-Tivadar, 2006).

Among others, Andre Kushniruk has in his several articles (Kushniruk et al., 1997; Patel and Kushniruk, 1998; Kushniruk, 2001; Kushniruk et al., 2005) expressed a concern about the evolution of usability evaluation methods in the evolving field of healthcare information technology. As technology applications become more complex, evaluation methodologies will need to be continually refined in order to keep pace (Kushniruk, 2001). This claim has been recently supported by Edwards et al. (2008), who have emphasised the need for predictive evaluation methods to accurately identify usability issues arising from the interaction, sharing, and communication requirements of clinical work. Wilson et al. (2007) have argued that evaluation strategies often fall short of evaluating real use by practitioners in the workplace and thereby miss an opportunity to gauge the true impact of the technology on the work. According to Kushniruk and Patel (2004) a challenge for future work on evaluation of healthcare information systems lies in the integration of data collected from multiple evaluation methods and the measurement of outcome variables.

Kushniruk and colleagues have also pointed out the need to consider *safety aspects* in usability evaluation studies. They argue that both technology and user-centred approaches should be employed before release of a complex healthcare IT system in order to ensure that it is safe and does not inadvertently introduce medical errors (Kushniruk et al., 2010). The relationship between usability and medical errors have also been pointed out by Fairbanks and Caplan, who argue that these errors can be facilitated by poor interface design and lack of usability testing (Fairbanks and Caplan, 2004). Kushniruk and Borycki have suggested the use of simulation-base analysis (Kushniruk et al., 2006a; Borycki and Keay, 2010), low-cost portable laboratory set-up (Kushniruk et al., 2006b), and safety heuristics (Borycki and Keay, 2010) to support the evaluation of usability and safety of healthcare IT systems.

Field study methods: Field study methods have not been widely adopted in the health informatics field, although the need for a participatory and user-centred design approach

in technology development has been strongly acknowledged. Recently, researchers (e.g. Alsos and Dahl (2008) and Horsky et al. (2010)) have suggested that, compared to the evaluation approach, field studies of clinical work are more suitable for informing conceptual problems and developing an understanding of the wider context in which the clinical information and communication media are used.

Experiences from field studies have indicated that ethnographic methods (such as interviews, observations, and artefact analysis) help efficiently explain relevant work practices (e.g. Weng et al. 2007; Reuss et al. 2007a). Furthermore, Malhotra et al. (2005), and Croll and Croll (2007) have stated that the methods used to derive the requirements for healthcare systems are often inadequate. According to them, the biggest risk faced in developing information systems and tools for a healthcare setting is to understand the complex environments that our health services present and ensure that the users appreciate and comply with any policies set.

Little can be found in the literature about the applicability of field study methods, particularly *contextual inquiry*, in healthcare technology development. Furthermore, some researchers have attempted to encourage user-oriented methods for assessing clinicians' needs and user requirements for system design purposes. By 1995, Colbe et al. (1995) had already argued that the contextual inquiry method has several advantages in obtaining a more comprehensive analysis of the true needs of users. In their review-based articles, Chan (2002) and Martin et al. (2006) introduced the contextual inquiry method with reference to its developers Beyer and Holtzblatt (1998), and explained the principles of the method.

Participatory design approach: Clemensen et al. (2007) have proposed that participatory design holds potential as a research approach that might effectively merge computer technology and health-related interventional research. Also, Pilemalm and Timpka (2007) have strongly argued on behalf of participatory assessment, and suggested the use of a participatory design-based method, *action design*, in the design of a large-scale healthcare information system. Based on practical experiences, participatory methods are thought to engage users in design, bring out the users' tacit work knowledge, and open design consideration possibilities (Weng et al., 2007; Hyysalo et al., 2007; Kyhlbäck and Sutter, 2007).

Usability testing of mobile solutions: Mobile and automated solutions to support end-user testing have recently emerged, making more feasible the combined evaluative approach that employs laboratory, field, and remote usability evaluations of new healthcare applications to derive its conclusions (Jaspers, 2009). Papers about usability testing of mobile solutions in clinical settings (Kushniruk and Patel 2004; Svanæs et al., 2010) are among the few articles reporting methodological lessons learned; Based on the experiences of these researchers, special attention should be paid to reflecting the realism and concreteness of healthcare contexts and the use of multi-perspective recordings when evaluating mobile applications in the clinical setting.

A mixture of usability methods: A recent study conducted by Horsky et al. (2010) is one of the few studies providing information about the comparison of usability methods and their applicability during healthcare technology development. The study incorporated four methods to obtain feedback: e-mail, questionnaire, usability evaluation, and interview. Their results suggested that no single method identifies all or most problems. Rather, each approach was optimal for evaluations at a different stage of design, as each approach characterised different usability aspects (Horsky et al., 2010). This argument has been supported by several researchers working in the health informatics field (e.g. Jaspers, 2009).

3.6 Studies Addressing Effects and Practices of Participatory IT Development

Although the relevance of and need for a user-oriented approach in healthcare IT development seems to be widely established, only a few researchers have systematically investigated the effects and practices on user involvement. A literature review by Shah and Robinson (2007) on the benefits of and barriers to involving users in medical technology development revealed that the main benefits of user involvement are associated with increased access to user needs and experiences, enhancements in design and user interfaces, and improvements in the functionality, usability, and quality of applications. Likewise, the determined key impediments in involving users include lack of resources, communication, and cooperation between users and developers; attitudes of technical developers; and lack of understanding and appropriate knowledge about methods to be used (Shah and Robinson, 2007). Furthermore, it has been argued that in healthcare IT system development there is a need for designers who have user interface and interaction design skills (Martikainen et al., 2010).

As might be ascertained from the findings of Shah and Robinson (2007), research on participatory healthcare technology development has paid relatively little attention to the viewpoint of the *developer – end-user* and *vendor – healthcare provider – physician* collaboration. Heeks (2006) introduced the concept of 'design–reality gap' with reference to misunderstandings and mismatches between the current realities and the design conceptions for healthcare information systems. He identified the two key stakeholders as system designers and end-users. Typically, empirical studies have not addressed these issues. As an exception, a user satisfaction study by Edsall and Adler (2005) included a question about the support and service provided by vendors. The results indicated that the physician respondents were generally happy with the service provided by their EHR companies. On the other hand, results from other empirical usability studies have encouraged the researchers to suggest recommendations and approaches for enhanced collaboration. Johnson et al. (2005) and Armijo et al. (2009) stress the need for a multidisciplinary approach involving collaborative effort between vendors, researchers, physicians, administrators, and others. Edwards et al. (2008) argue for healthcare providers to promote participatory development when selecting healthcare IT vendors. They suggest a selection criterion related to end-users' feedback on system use to provide the vendors data for further development work and improvement in the usability characteristics of healthcare IT products.

3.7 Summary

The review of usability-related research in the health informatics field showed that usability evaluation studies have become more important during recent years: many researchers have explored the use of large-scale healthcare information systems and reported usability problems. Despite the trend, which seems to indicate an increase in complaints and beliefs related to the lack of usability of large-scale healthcare IT and ICT applications, relatively little systematic data has been gathered on the user-friendliness of the healthcare technology environment in which clinicians work daily. Generally speaking, results from usability studies have provided only limited answers to the question of clinical ICT system usability, since the focus in research is heavily affected by the traditional approach to human-computer interaction evaluation – namely, evaluation of human-computer interaction and the characteristics of a user interface.

To summarise, the review findings indicated that usability-related research in the field of health informatics is characterised by the following aspects:

- *Narrow focus on user and usability issues.* The studies do not consider user issues broadly, but instead focus on one of the many user-oriented aspects: a single end-user group perspective, user interface components, or use of the system in a specific context.
- *An emphasis on summative evaluation rather than on design or development.* Often, usability evaluation studies discuss summative usability results on working systems; this leads to a focus on the problems with adopting current systems in a given healthcare environment and diverts concentration from the design or development of new, better systems.
- *Isolated system development.* Studies that report system design and evaluation activities rarely discuss the relationship between a) single-system development and the existing technology setting in healthcare, or b) the characteristics of various use contexts.
- *An emphasis on information systems and data management, instead of on designing systems to support communication and collaboration.* Although a considerable amount of research has been devoted to information system development in the healthcare context, less attention has been paid to the investigation of communication technologies and their potential for supporting the work of healthcare professionals and patient-provider communication.
- *Focus on later activities and phases of interactive system development rather than on description of context of use or specification of user requirements.* The human-centred design process for interactive systems, described in the ISO 13407 (1999) and ISO 9241-210 (2010) standards, includes four UCD activities: specify context of use, specify user requirements, produce design solutions, and evaluate the design. Based on the literature review, a significant number of usability-related studies concentrate on evaluation and design activities, and only a few report user research activities aiming to understand and specify the context of use. Surprisingly, none of the reviewed articles dealt with user requirements specification activities.

Furthermore, quantitative studies, for instance structured questionnaires on user satisfaction and acceptability, usually discuss summative results and thereby do not provide information rich enough to support design decisions made during development. In order to gather information about user and contextual aspects and to address key requirements and support the development, user-oriented research needs to be explanatory or interpretative by nature. Based on these findings, there is an increasing demand for broadening the scope of usability work: conducting usability studies from the end-user's perspective in real-life surroundings, understanding the contextual aspects of usability, incorporating user perspectives in the design and development, and adopting appropriate approaches and methods.

4 THESIS OBJECTIVE: ENHANCING CLINICAL ICT DEVELOPMENT WITH USABILITY WORK

Thematically, the thesis research includes three viewpoints: empirical, conceptual, and methodological. Of these, conceptual and methodological viewpoints are to complement the empirical viewpoint. The following paragraphs describe these viewpoints and the related eight research questions.

The empirical viewpoint. The objective for this viewpoint is to study the use of clinical IT systems, identify possible usability and interaction design-related problems, and based on study findings, suggest improvements to overcome the problems for the purposes of furthering user-centred system design.

The research questions are as follows:

Question 1) ***From the perspective of clinicians, how do the currently used IT systems support their everyday work?***

Question 2) ***What are the critical usability and interaction design-related problems?***

Question 3) ***How should the identified problems and challenges (Q1 and Q2) be overcome: What kind of improvements do the empirical study findings suggest?***

The thesis includes three empirical studies that explore usability by using field study methods in clinical surroundings. These methods are employed to gather data about clinicians' needs, requirements, and expectations towards ICT systems in environments where numerous information systems are being used. The studies are as follows:

Study 1: Digital dictation study – contextual inquiry study on dictation procedures, and use of related IT systems from a physician's viewpoint (Papers I, III, and VI)

Study 2: Evaluation of nursing documentation systems – a usability evaluation of four nursing documentation systems from the nurses' perspective in real-life surroundings (Papers II and III).

Study 3: Questionnaire study with physicians – a national questionnaire study on physicians' experiences on the use and usability of their clinical IT systems, and related development activities (Papers IV and V)

On a general level, the studies incorporate the following steps: (1) analysis of the usability of clinical IT systems from the perspectives of end users, (2) gathering and analysis of user data, (3) identification of and elaboration on problems and challenges, and (4) description of possible areas of improvement. The research was carried out utilising several UCD methods: contextual inquiry, interaction sequence illustration analysis, usability inspection, and tailored usability questionnaire methods. The studies involved clinicians from various healthcare units, and thereby reflect the characteristics of diverse clinical working contexts.

Conceptual viewpoint. The objective for this viewpoint is to examine usability in the context of clinical work: What is meant with "usability of clinical ICT systems"? What aspects of usability (dimensions or attributes) should be examined in empirical studies? The aim is to increase the understanding of contextual aspects of usability in healthcare settings by a) reviewing the academic literature based on empirical studies available in the health informatics field b) describing conceptualisations for the *usability of clinical ICT systems*, which particularly reflect the clinicians' perspectives on technology use and the characteristics of clinical work.

The research questions are as follows:

Question 4) What is the scope of usability in the context of clinical IT system research?

Question 5) What are the specific aspects that should be addressed when studying the usability of clinical ICT systems in healthcare contexts?

The fourth question aims at making observations on the application and scope of usability in the health informatics field compared to common definitions in UCD and the usability research field (e.g. presented by ISO 9241-11 (1996) and Nielsen (1993)). In the context of this thesis, usability is understood as a broad concept that includes multiple aspects (e.g. perceptual and emotional) and issues ranging from temporal dimensions to user goals (as described earlier in chapter 1.4 on pages 8 and 9). This broad view on usability is derived from the endeavour of the UCD approach to understand the concept of usability as a multi-dimensional property that is highly dependable on the context of use. The common misconception still is that usability refers solely to making systems easy-to-use (ISO 9241-210, 2010). Furthermore, the usability testing approach typically aims at finding out how the user interface supports the users to do their tasks (e.g. UsabilityHome website[9]). Thereby, the thesis emphasises a user-centred and task-centred approach to research, in contrast to system-centric and testing-driven assessment. Such an approach is well-aligned with both the

- widely referenced definition of usability, the ISO 9241-11 (1998) standard: *usability is the extent to which a system can be used by specific users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use*.
- recently established aims of user-centred evaluation by ISO 9241-210 (2010) standard: *collect new information about user needs, provide feedback on strengths and weaknesses of the design solutions from the user's perspective, assess whether user requirements have been achieved, and establish baselines or make comparisons between designs.*

Examination of the contextual aspects of usability, specifically for clinical contexts, builds on earlier usability-related research in the health informatics field (described in chapter 3). Also, in empirical studies, usability is studied from a broad perspective – usability issues deriving from the characteristics of clinicians' work and clinical contexts.

[9] UsabilityHome website: http://www.usabilityhome.com/. In the website three types of usability evaluation methods are described: Testing, Inspection, and Inquiry.

Methodological viewpoint. The third objective of the thesis is to analyse, assess, and adjust UCD methods for the development of healthcare ICT systems. The research questions are as follows:

Question 6) ***Are the clinicians interested in contributing to the development of their clinical IT systems? What kind of experiences do clinicians have with respect to current development activities?***

Question 7) ***Based on empirical studies, what are the perceived advantages and challenges in using the UCD methods in the research of clinical ICT system use?***

Question 8) ***What are the characteristics of clinical contexts that need to be taken into account when applying UCD methods?***

In the UCD research field, the range of existing methods for the design and evaluation of interactive systems as well as for conducting user research is extensive. As indicated by the literature review (Chapter 3), researchers have typically applied traditional evaluation methods in studies, but other UCD methods to support design and development activities of clinical IT systems have not been widely used. Therefore, little is known about the applicability and suitability of these methods, such as contextual inquiry, in the context of clinical practice. Likewise, healthcare-related topics have only recently gained interest among UCD practitioners. Based on these findings, the understanding of the characteristics of clinical contexts and related challenges for applying and adjusting UCD methods seems to be limited. Question 8 addresses these issues. In this thesis, contextual inquiry, a tailored usability questionnaire, and interaction sequence illustration methods were applied in the empirical studies. Research question 7 will be answered based on methodology experiences gathered during and after these studies. Since the overall aim of this thesis is to gain improved understanding of the applicability of the UCD approach in the health informatics domain, it is also important to understand the challenges and possibilities of user involvement from the end-users' perspectives (question 6).

5 THREE STUDIES ON CLINICAL IT USABILITY IN FINLAND

This thesis includes three empirical studies on clinical IT usability (Table I). The context of the research is healthcare environments in Finland – more specifically, clinical surroundings in which physicians and nurses are the primary users of clinical IT systems. The studies were conducted between the years 2008 and 2010. The following provides an overview of the research context (healthcare IT use and development in Finland) and the study aims, methods, and procedures of the three studies.

Table I. Summary of three studies on clinical IT usability.

Study	Focus and objectives	Methods	Users	Clinical IT systems	Paper
Digital dictation study	Study dictation procedures from physicians' viewpoints, describe user needs	Contextual inquiry Interaction sequence illustration	7 hospital physicians	4 dictation techniques, related clinical IT systems	I, III, VI
Evaluation of nursing documentation systems (NDSs)	Evaluate use and usability from nurses' perspective, study nurses' experiences with use	Contextual inquiry (Expert review)	18 nurses from seven healthcare organizations	Four nursing documentation solutions in EHR systems	II, III
Questionnaire study with physicians	Explore physicians' experiences on the use and development of their clinical ICT systems	Questionnaire (Pilot tests using interviews)	3929 respondents (physicians) (5 pilot test users)	Clinical technology environment, including numerous IT systems	IV, V

5.1 Context of the Research: Finnish Healthcare

The Finnish healthcare system is characterised by its own unique set of structures set up for the purpose of delivery of care, and also has its own unique history of healthcare information system development and use. Preventive and primary healthcare services are arranged locally and organised among healthcare centres operated by municipalities. In principle, the municipalities have the responsibility to provide care for and arrange social and healthcare services for people living in their areas.

To be more specific, in Finland specialised healthcare is provided by 20 federations of municipalities called *hospital districts*. Specialised healthcare organisations cover a spectrum of hospitals, ranging from regional hospitals to central and university hospitals. Public healthcare services, provided by public healthcare centres and public hospitals, are mainly financed by taxes. In year 2007, private healthcare covered 31% of all outpatient visits nationally and 65% of specialist visits (THL, 2010).

In Finland, information systems are widely used in healthcare. EHR systems cover 100% of the specialised and primary healthcare organisations (hospitals and healthcare centres) (Winblad et al., 2008). As a result of progress in electronic information exchange between organisations, fully interoperable patient data exchange is regionally in operational use in most healthcare institutions (Winblad et al., 2008; Iivari and Ruotsalainen, 2007).

IT systems used in Finnish healthcare are locally developed. The most obvious reasons for this derive from the language barrier, the small market size, and the special characteristics of healthcare delivery that have made Finland unattractive to international vendors. In principle, each healthcare centre and hospital district has the possibility of independently deciding which IT systems to procure. Currently, the two large vendors share the bulk of the market in all healthcare sectors.

The already comprehensive basic IT infrastructure in healthcare is seen as a strong area in the further development of eHealth (Reponen et al., 2008). At present, a national archive for electronic healthcare data with citizen access is under development. The aim is to 1) create a new working environment for professionals through incorporation of innovative information and communication technology, new organisation of work, and re-engineering of workflows, and 2) offer the citizens a possibility to actively participate in decisions on their care, carry out guided self-care, and take steps of proactive prevention (Harno and Ruotsalainen, 2006). To go into more detail, the plan is to provide citizens with:

- reliable information on the following: health promotion; the symptoms and treatment of illnesses; service providers in the public, private, and third sectors; the content, availability, cost, and quality of service; and their benefits and rights; and
- a variety of interactive services, such as appointment booking; consultation; interpreter services; Q&A; virtual discussion forums; and self-help systems for chronic illnesses. (Iivari and Ruotsalainen, 2007)

The strategy for utilising information technology in the field of social welfare and healthcare was published in 1996 and redefined in the year 2006 (Ruotsalainen et al., 2008). The updated strategy defines the principles for how digitised health records should be stored, accessed, disclosed, and archived.

The electronic archive is expected to have a central role in the communication of information between healthcare organisations and units during treatment of patients (Kela, 2010; Iivari and Ruotsalainen, 2007). The objective is to store patient records in a uniform technical format, ensuring their portability across systems and improving their availability to healthcare providers (Kela, 2010). The effects of national archive development activities extend to nursing work, which is why practices for electronic nursing documentation are currently evolving. While a few Finnish healthcare organisations still rely on paper-based documentation and processes, electronic nursing documentation systems (NDSs) have been in use in many Finnish healthcare organisations for several years. Currently, the adoption of a national documentation model and the successful implementation of nursing documentation applications in EHR systems are timely topics for research (e.g. Kuusisto et al., 2009; Häyrinen et al., 2010; Ala-Hiiro et al., 2010).

The effects of new technology adoption in the Finnish healthcare sector are manifold, as is the case in other industrialised countries, and the success of healthcare information systems is an ongoing topic of discussion. Although Finnish healthcare professionals are generally considered to have good ICT skills (World Health Organisation, 2008), recent studies have pointed out both advantages and serious challenges in technology adaptation and use in clinical settings (Walldén et al., 2007; Winblad et al., 2009; Winblad et al.,

2010; Hyppönen et al., 2011a). With regards to the national archive, several challenges relating to implementation of the norms, standards, and interoperability of information systems exist due to the fact that healthcare providers are decentralised (Iivari and Ruotsalainen, 2007).

Recently, public discussions have been held on the future direction of healthcare IT development at the national level. Related concrete actions include a study on the suitability of leading international health record systems for Finland's healthcare system (Sitra, 2011). The results indicate that the single-health-record system model is a viable option for Finland; however, this would require the creation of the roles for a national level purchaser and executor, as well as amendments to legislation to enable national-level steering that was legally binding on healthcare organisations (Sitra, 2011).

5.2 Digital Dictation Study (Papers I, III, and VI)

The digital dictation study was carried out in spring 2008 in a large hospital in Finland. The study had three objectives:

1. describe the dictation processes from the physician's viewpoint,
2. compare the currently used dictation techniques with each other; and
3. ascertain physicians' opinions concerning mobile dictation solutions.

During the study time period, various dictation techniques, procedures, and types of equipment were used in the hospital. The dictation study was part of a larger research and development project aimed at supporting future decision-making and investments relating to electronic documentation in the target hospital. The study especially focused on researching digital dictation procedures, since from the viewpoint of the administration of the hospital digital dictation was the most promising solution for future use.

The dictation study incorporated two usability research methods: contextual inquiry that was enhanced with interaction sequence illustration analysis. The contextual inquiry followed the established principles of the method (Beyer and Holtzblatt, 1998) and was seen as a suitable approach for exploring the currently used dictation techniques in their real context of use (clinical work in wards, clinics, and office), since the flexible structure of a semi-structured interview would allow the researcher to generate questions during the interview based on interviewee responses. Three topics were covered in the contextual inquiry:

- Background, including education and current job description, information technology skills and enthusiasm, dictation methods and experiences
- A dictation walkthrough in practice: the beginning of the dictation, dictating, and a discussion of performed activities
- Futuristic views: evaluating and discussing the mobile phone dictation concepts. (Figure 3 shows an example of an evaluated concept. The concepts were created together with hospital representatives, and were used for discussions of new dictation solutions.)

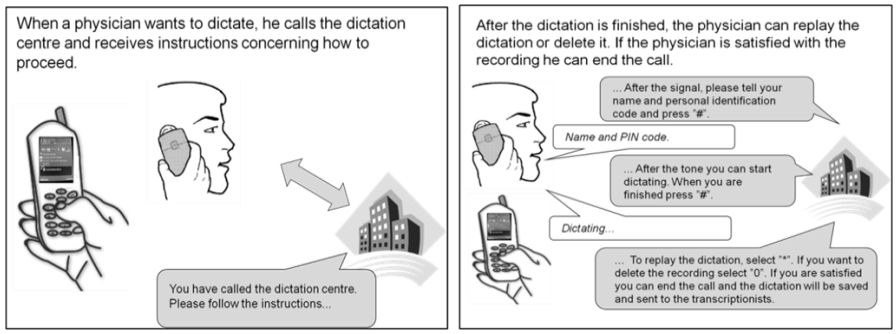


Figure 3. An example of a mobile phone dictation concept. (Paper I)

Data gathering was conducted with seven physicians who were accustomed to using a variety of dictating methods and tools in their daily working environments. The physicians were asked to perform a dictation sequence as they normally would and (while working) describe and provide the reasoning behind their actions. A voice recorder and a digital camera were used to record the interviews for later analysis.

An interaction sequence illustration (ISI) analysis was to supplement the inquiry data and focus on digital dictation procedure, user interface issues, and low-level analysis of human-computer interaction. The idea behind this was to identify and document all interaction steps in digital dictation procedure that occur between a user and the tools used to take dictation. Data for the low-level interaction analysis was gathered after the inquiries in collaboration with a chief physician who dictated daily using the digital technique. The chief physician was asked to slowly conduct a realistic dictation procedure from its beginning to ending stages. Meanwhile, the researcher observed the process and captured screenshots after every interaction step.

Study data consisted of two sets of documented information: 1) typed notes and photographs from the contextual inquiries, and 2) sets of screenshots illustrating interaction between the physician and a system in dictation process. Data from the inquiries was analysed using the affinity diagram method (Beyer and Holtzblatt, 1998) and interpreted together with the hospital project members in a team sharing session. The interaction analysis outlined and described the stages of interaction specific to each of the three dictation techniques, and illustrated the interaction steps in the digital procedure. At a practical level, the analysis included organisation and modification of the pictures, as well as highlighting of the details of conducted interactions.

The study procedure, methods used, and background information about the involved users are described in more detail in **papers I**, **III**, and **VI**.

5.3 Evaluation of Nursing Documentation Systems (Papers II and III)

A study of electronic nursing documentation systems (NDSs) was conducted in Finland in spring 2010 to evaluate the usability of four currently used systems and research how the usability aspects appear in nurses' documenting practices.

The usability criteria were drawn from the definitions of usability by ISO 9241-11 standard (1998) and Nielsen (1993), and included five of the most apparent attributes that illustrate characteristics of nursing context of use and objectives that the end-users of NDS have: fluency of documentation, accuracy and correctness of documentation, ease

with which the system can be learned, usefulness of the documented information, and collaborative use of the documented information.

The study incorporated two usability methods: contextual inquiry (Beyer and Holtzblatt, 1998) and expert review using usability heuristics (Nielsen, 1993). The contextual inquiry included 18 nurses from seven healthcare organisations and was conducted in Finnish in nurses' real working environments. The predetermined themes for the interviews included a) documentation in nursing work, b) a practical documentation exercise based on the pre-written scenario, c) use of patient information for one's own purposes and in collaboration with other professionals. During the inquiry, the documentation exercise was the main theme and incorporated several other topics. Before data gathering, the researchers had prepared three textual scenarios: one to fit for primary healthcare, others for clinic and ward in special care. In the exercise, the nurse was asked to envision a nursing situation described in a scenario, document information as he or she would normally, and (while working) explain and provide the reasoning behind her actions.

In the study, expert reviews supplemented data obtained from the contextual inquiry and focused on user interface details and low-level analysis of human-computer interaction. Reviews were conducted for each documentation system after the contextual inquiries had been performed with nurses using a particular NDS. The reviews were conducted by a research group member who is a usability specialist, and who had background knowledge about the nurses' actions with their documentation systems based on the inquiries. After the inquiries, the researcher took screen captures of the main phases of documentation procedure, and thereafter evaluated the user interfaces with the usability heuristics. In the analysis phase, all the qualitative data was iteratively classified into several content categories arising from the data and then grouped together with the NDS usability attributes.

The study procedures and the methods used are described in **papers II** and **III** (published in conferences). As mentioned in Paper II, the study of NDS was a part of an empirical research project which incorporated three intersecting themes: 1) the feasibility of the Nationally Standardized Electronic Nursing Documentation Model in nursing practice, 2) the usability of NDS, and 3) the role of nursing documentation in multi-professional care work. The procedure of the whole research project as well as detailed information about the studies are reported in other publications (project report in Finnish by Nykänen et al. (2010) and journal article under review by Nykänen et al. (2011a)).

5.4 Questionnaire Study with Physicians (Papers IV and V)

The national questionnaire study aimed to study physicians' experiences of use, usability, and development of clinical information systems and communication technology applications, and thereby provide a generalised picture about advantages, problems, and challenges that were related to the technology. The study on physicians' experiences was designed in a multidisciplinary group coordinated by the Finnish Medical Association. The questionnaire was targeted to Finnish physicians who were under the age of 65 years and actively engaged with clinical work in public healthcare centres and hospitals or in private provider organisations. The questionnaire included questions about usability, information system success, user-oriented participatory technology development, and working environment.

The process of questionnaire design was iterative. The first version of a questionnaire form, particularly contents of the questions, was evaluated by three physicians representing the target group. Later on, the questionnaire was pilot-tested with five

physicians. After the pilot tests about 30 small refinements were made to the questionnaire form.

The web-based questionnaire was in Finnish and included 38 questions. The reason for constructing a web questionnaire was to follow the prevailing practices of the Finnish Medical Association and utilise the advantages of electronic data gathering and analysis. At the beginning of the questionnaire, there were 16 questions regarding the clinical physicians' backgrounds and their experiences in using healthcare information systems. The main part of the questionnaire consisted of 16 sets of research questions, each with about 5 sub-items formulated as positive or negative statements with a five-point Likert scale (strongly agree to strongly disagree). In addition, two of the research questions were open-ended and four were multiple-choice questions. The respondents were asked to reply from the viewpoint of those clinical IT systems they mainly use, with particular interest in the EHR system, and in the context of where they work most of the time. **Papers IV** and **V** describe the questions in more detail.

The web-based questionnaire was available from mid-February to mid-March 2010. During that time 3929 physicians, representing one third of physicians working actively in clinical work in Finland, replied to the e-mail invitation sent by the Finnish Medical Association. Based on the background information, the demographics of the respondents indicated a high correlation between the responding physicians and all working-age physicians in Finland (Vänskä et al., 2010). The statistical analysis was conducted using SPSS software, whereas the analysis of the qualitative data followed the principles of the content analysis method (Weber, 1990).

Of the data gathered on physicians' experiences on their currently used IT systems, **paper IV** focuses on usability, and **paper V** on results related to participatory development.

6 RESULTS: MISMATCHED IT – OPPORTUNITIES FOR USER-CENTRED DEVELOPMENT

This chapter summarises findings from the three empirical studies. The results are described in more detail in the papers attached at the end of this thesis.

6.1 Physicians' Ratings for EHR Systems

The national questionnaire study with nearly 4000 respondents showed that Finnish physicians are highly critical of their currently used IT systems. The averages of the grades given to EHR systems reflect physicians' dissatisfaction: with a rating scale from 4 to 10, the average grade varied from 6.1 to 8.4 (Table II). Deeper analysis revealed that dissatisfaction with EHR systems was highest in the municipal sector (public hospitals and healthcare centres). What make the findings even more concerning is that systems with larger user populations (systems E = Effica, J = Miranda-Oberon and I = Pegasos) received relatively low ratings (averages between 6 and 7). (Paper IV)

Table II. Physician's overall ratings for their principally used EHR systems. (Paper IV)

EHR system (product name)	Healthcare sector in which the system is used	Respondents (n)	Mean opinion score (4-10)	Std. Deviation
A (Medicus)	private providers of healthcare services	36	**8.4**	1.2
B (Softmedic)	private providers of healthcare services	74	**7.2**	1.0
C (Doctorex)	private providers of healthcare services	258	**7.2**	1.0
D (ESKO)	public hospital	154	**7.2**	1.2
E (Effica)	public healthcare centres and hospitals	632	**6.9**	1.1
F (Graafinen Finstar)	public healthcare centres	37	**6.9**	1.3
G (TT2000)	private providers of healthcare services	54	**6.7**	1.2
H (Mediatri)	public healthcare centres and hospitals	110	**6.3**	1.6
I (Pegasos)	public healthcare centres and hospitals	350	**6.2**	1.2
J (Miranda-Oberon)	public hospitals	610	**6.1**	1.2
Other		167	**6.6**	1.4
Total		2482	**6.6**	1.3

In addition, physicians' desires for future systems are mainly concerned with improvements to make the currently used systems simpler, more reliable, and quicker to use. Many of the open-ended comments pointed out generalisable user requirements for the ICT systems, especially regarding usability issues. Thus, these findings further indicate that the use of the current systems in clinical work is hindered by usability flaws. (Paper V)

Although EHR systems represent only a part of the IT environment in clinical settings, they are the main tools physicians use in their daily work with patients, and are often integrated together with other systems, or at least used in parallel with other systems. Therefore, grades given to these systems can be considered as reflecting physician experiences with wider aspects of currently used clinical IT applications.

6.2 Fluency of Documentation and Information Retrieval

Results from the questionnaire study indicated that current clinical IT systems are poorly suited to the requirements of information management tasks. For example, only 5% of responding physicians strongly agreed with and 23% agreed with the statement 'I find it easy and fluent to manage patient information (document and retrieve data) using the information systems.' (Paper IV)

The digital dictation and nursing documentation system (NDS) studies investigated in particular the practices and procedures of clinical documentation in the context of a real-life clinical setting. This applied research approach (field-study methods in real-life surroundings) enabled pointing out the problems and also describing the reasons behind these problems.

The study of NDSs showed that none of the evaluated four systems supported effective or efficient documentation– documentation requires a lot of time because of poor user interface design and complicated interaction sequences. Time required for documentation is considerably higher because the nurses are forced to take a huge number of unnecessary interaction steps when performing a simple task, for example a new documentation entry. When the nurses are to select classifications for their entries (in Finland the FinCC includes three hierarchy levels and 719 classes (Häyrinen et al., 2010; Tanttu and Ikonen, 2006) the system does not follow the nurses' mental models or provide intelligent support for searching for or writing down these classifications. Instead, the implementation forces a user to proceed in a top-down fashion (from abstract to concrete). The evaluated systems also poorly supported the use of structured templates or copy functionality, in spite of the fact that the contents of patient documentation within a clinic or a ward typically follow the same structure. Additionally, the nurses are required to document the same information several times into different systems because of lack of automatic transfer and integration. (Paper II)

Similarly, the observed procedure of digital dictation was found to be inefficient and unnecessarily lengthy from the physician's viewpoint. The observed dictation solution was closely integrated with the EHR system. Findings from the interaction analysis indicated that the dictation process consists of nine stages of interaction (Table III) and involves several complicated steps. Compared to both conventional cassette dictation and advanced voice-recognition techniques, the number of steps and stages is considerably higher (Table III). Furthermore, more than 60 interaction steps were counted during a simplified digital dictation procedure. This indicates the complexity of the digital dictation procedure from the viewpoint of the physician. Contextual inquiries revealed that most of these complexities are due to problems in EHR user interface design. (Papers I and VI)

Table III. Illustration of dictation procedures: stages of interaction in digital, cassette, and voice-recognition dictation (Paper VI).

Stage of interaction	Digital dictation	Cassette dictation	Speech recognition dictation (radiology)
1.	Start up the computer, log in, and open EHR system.	Fill in the dictation paper form (patient identification information).	Open the CRIS radiology information system.
2.	Find the target patient information in the EHR system (using his/her social security number).	Other preparatory actions e.g. stick a note to a cassette and insert the cassette into a recorder.	Select the target patient from the list (→ the patient's pictures will open).
3.	Open up and become familiar with previous documentation using electronic health records and other related systems.	Become familiar with patient documentation using papers and electronic information systems.	Dictate (while modifying the pictures) using a handset. The dictated text appears on screen in almost real time.
4.	Dictate (including identification information and dictated message) using a handset.	Dictation (including identification information and dictated message) using a handset and a recorder.	Edit (using the keyboard) and save the dictation (using the handset).
5.	End and save dictation.	Put cassette and papers into an envelope. (Nurses will deliver the envelope from the physician's desk further.)	
	Dictation is converted from voice to text by transcriptionists and is returned to the physician within several days.		
6.	Find the notification about the transcribed dictation.	Review, and if necessary, make revisions with paper and pen; deliver paper to nurses.	
7.	Search for the dictation using the EHR system.		
8.	Review and, in necessary, make corrections; save the approved dictation.		
9.	Mark the notification as having been checked.		

In the dictation study, user requirements were to illustrate those needs, wants, and desires that physicians have for a dictation solution, as well as the constraints that arise from the clinical contexts of use (Table IV). Furthermore, the described seven requirements were used as criteria for evaluating the currently used dictation techniques and procedures. The comparative analysis showed that of all the three evaluated techniques, voice-recognition dictation was found to be most suitable for general-level user requirements; digital dictation was the least suited (Table IV). (Paper I)

Table IV. User requirements for a dictation solution and summary of comparative analysis (Paper I).

Criteria (identified user requirements for dictation solution)	Cassette dictation	Digital dictation	Voice-recognition dictation
1. The physician should be able to dictate at any opportune moment.	+	–	+
2. While dictating, the physician needs to have access to various patient information resources.	–	–	+ / –
3. The dictation solution should be simple and easy to use.	+	–	+
4. The dictation solution should tolerate prolonged pauses.	–	–	+
5. The physicians should be able to perceive the dictation as a whole.	–	–	+
6. The dictation solution should support silent, independent working.	+ / –	+ / –	+ / –
7. The dictation process and solution should fit the intended context of use.	+ / –	+ / –	+

The following examples illustrate some of these findings on a more concrete level, taking requirements 4 and 5 as their starting point:

- *Requirement 4*: *The dictation solution should tolerate prolonged pauses*. According to physicians, pauses and interruptions are common. During dictation, physicians often pause and consider the contents of dictation and how to continue. Phone calls and questions from nurses and colleagues can also cause interruptions. Sometimes, the physician may even need to suspend the dictation and return to it later on.
- *Requirement 5*: *The physician should be able to perceive the dictation as a whole.* The length of a dictation may vary greatly, as does the time required to dictate one. In particular, lengthy dictations enhanced with complex content can be difficult to outline. When the dictation is performed using a recorder, the physician has to piece together the dictated message in her mind. To facilitate the process, physicians sometimes sketch lengthy dictations using a pen and paper.

Findings from comparative analysis suggested dictation system-related problems with respect to these two requirements. Cassette dictation and digital dictation share the same primary problems in comparison to voice recognition and typing. It is difficult to perceive the dictation as a whole when recording the dictation in audio format. After an interruption, the physician usually has to rewind the tape to listen to the previous part of the dictation. If the dictation has complex content and the interruption is lengthy, it is even more challenging to summon up the thoughts that were originally intended and continue. Theoretically, both cassette and digital dictation allow physicians to suspend the dictation and return to it later; however, for practical reasons, the physicians favoured recording dictation anew rather than pausing and continuing at a later time. In contrast to these techniques, the advantages of the voice-recognition dictation procedure is that the dictated text appears on a screen almost in real-time, and thereby enables the physicians to structure the dictation while dictating as well as to make necessary changes using text editing. (Paper I)

6.3 Usability of Clinical IT System User Interfaces

In the questionnaire study, a set of statements was developed to address usability of EHR user interfaces. Physicians expressed fairly positive opinions about the user interface characteristics (e.g., terminology and feedback) and the intuitiveness of use. These opinions were more positive than were their opinions on other subjects related to the interfaces (Table V). Physicians expect their IT systems to provide better support for performing routine tasks than they currently do. Physicians' responses indicated that routine tasks cannot be performed in a straightforward way, and that IT systems require physicians to perform fixed sequences of steps and tasks. (Paper IV)

Table V. Examples of results: summary of questionnaire items on usability of EHR user interface and learnability (Paper IV).

Statements	Strongly agree %	Agree %	Neutral opinion %	Disagree %	Strongly disagree %
The EHR system responds quickly enough to inputs.	9	38	16	27	10
I perceive the arrangements of the fields on-screen as sensible for the work I do.	8	35	18	26	12
The EHR system provides me appropriate feedback about the tasks it performs (e.g., when it is saving data).	7	30	22	30	12
The terms and concepts used in the EHR system are clear and unambiguous.	9	39	19	23	9
I find it easy to learn how to use the EHR system.	14	40	16	20	10
Learning to use the EHR system does not require long training.	10	34	20	24	12

Difficulty in learning to use clinical IT systems was emphasised by several nurses during the contextual inquiry of the NDS study. Nurses felt that learning how to create standardised documentation with a documentation system is time consuming and demanding. Findings from the expert reviews indicated that none of the evaluated four systems are intuitive to use, as the systems do not guide the users in information processing. Because of separate systems and a lack of integration among the different systems, the situation is even more complicated for new users. (Paper II)

Another problem relates to accuracy of nursing documentation. The NDSs allow the nurses to use a variety of documentation practices at both the content level and the technical level. These practices in healthcare organisations rely on the unit's own, commonly agreed on instructions, and on the nurses' own experience and knowledge. Due to the complexity of the user interfaces, the users can easily make errors in performing the documentation. Generally, the system's support for failure protection is insufficient. Accuracy of information is no doubt endangered because of these facts and

because of the insufficient guidance for users in a documentation process. Nurses (especially when they are in a hurry, as would often be the case in the context of a clinic or hospital) must try to use the NDSs in a simplified and straightforward manner; however, this may reduce the quality of documentation. (Paper II)

The following figure (Figure 4) shows pictures taken of two evaluated NDSs user interfaces (these systems were implemented into two widely used EHR systems, which product names are Miranda and TT2000). The views illustrate the multiplicity of user interface components and the overall ambiguity of documentation user interfaces. The pictures do not include real patient data.

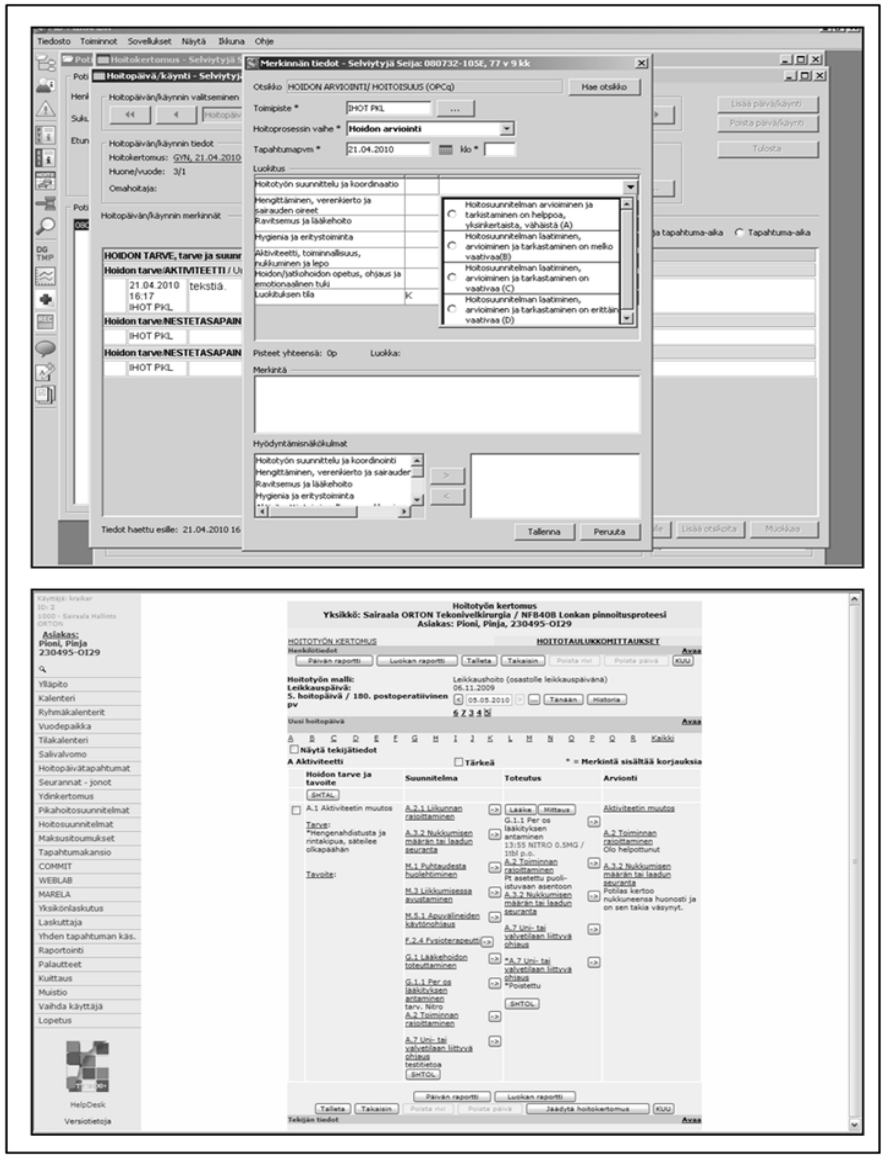


Figure 4. NDSs user interfaces are characterized with multiplicity of user interface components.

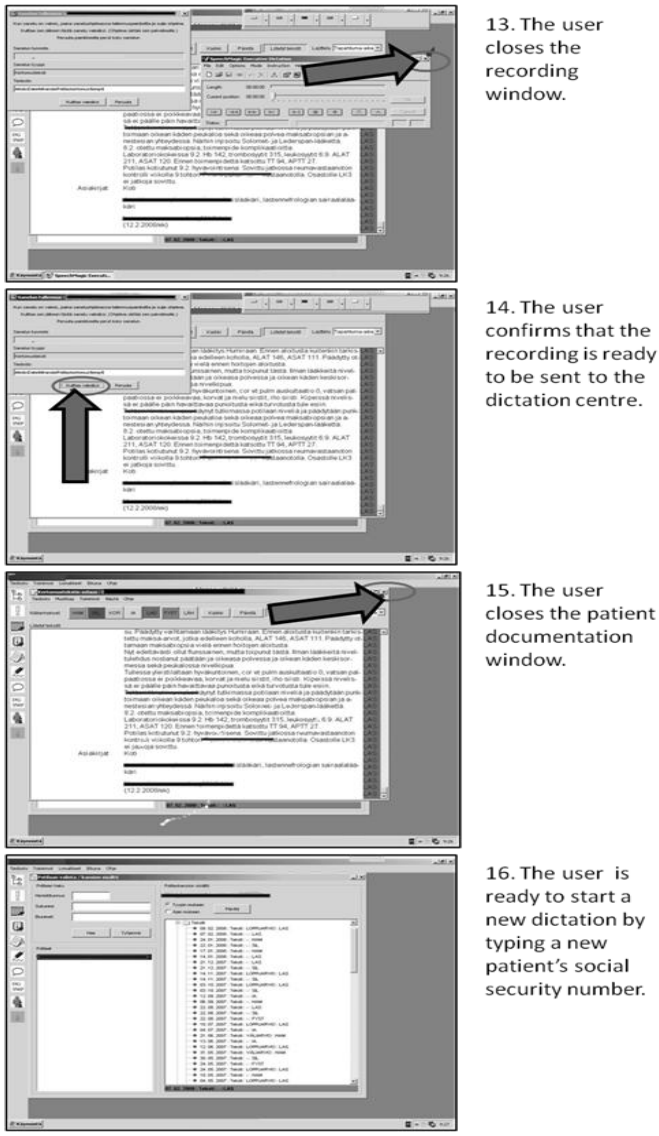


Figure 5. Illustration of user interfaces and required interaction steps during the digital dictation procedure. The user must perform numerous interactions when finishing the recording. (Paper VI)

Findings from the digital dictation study indicated that usability problems in EHR user interfaces are more plentiful and severe than the questionnaire results suggest. The interaction analysis revealed dozens of usability problems, although the detailed evaluation of user interface characteristics was not the focus of the study (Paper VI). The analysis showed that most of the usability problems related to the procedure of digital dictation are rather obvious and apparent. For example, before starting the dictation numerous interactions should be performed to select the right patient, search patient data, read through earlier documentation, type identification codes, and so on. Similarly,

finishing the dictation − stopping recording and sending the recorded file − includes several interaction steps before the physician can start a new dictation (Figure 5, the product name of the EHR system in the pictures is Miranda).

Probably the most striking example of poor user interface design is the technical implementation of a notification informing the physicians about transcribed dictations. The notification of a transcribed dictation waiting for confirmation did not appear in the EHR system or the desktop, but instead compelled the physicians daily to open the 'personal checklist' application and check for possible notifications. Although the notification informed the physician about written dictation, it did not include a link to the dictation text. Therefore, physicians needed to use the notified social security number when seeking the dictation text for that patient from the EHR system. (Papers I and VI)

6.4 ICT Support for Clinical Tasks

The questionnaire responses indicated that the current healthcare IT systems lack key functionalities, such as a proper patient overview chart (daily treatment chart), and also lack supports for decision making and for the prevention of medical errors (Table VI). Furthermore, most respondents disagreed with the statements on efficiency of system use. (Paper IV)

Table VI. Example of questionnaire results: physicians' responses to statements about key functionalities and efficiency of use. (Paper IV)

Statements	Strongly agree %	Agree %	Neutral opinion %	Disagree %	Strongly disagree %
Key functionalities					
Systems provide support for decision making (reminders and warnings).	4	18	27	29	21
Systems help to prevent medication errors.	3	25	20	29	22
EHR provides a proper summary view (daily treatment chart) about the situation of the patient. *	1	7	9	19	19
Efficiency of use					
Routine tasks can be performed in a straightforward manner using the EHR system.	9	27	14	29	21
I find it easy and fluent to manage patient information (document and retrieve data) using the information systems.	5	23	18	36	18

* 44% of the respondents reported being short of this functionality.

Similarly, the nursing study indicated that nurses experience difficulty obtaining a general view of the patient's situation and needs, as well as of previous actions taken in caring for the patient. The reasons for this included: fragmentariness of structured documentation, documentation into separate systems, lack of summaries, and inappropriate manner of information presentation for readers. Instead of presenting summaries, documentation is composed of small data and information items according to the classification. Furthermore, earlier documentations are difficult to utilise when documenting the patient's care. The systems poorly support the use of structured templates or the copy and paste functionality, although the contents of patient documentation within a clinic or a ward typically follow the same structure. In general, the inquiries suggested that a good deal of the nurse's work time is occupied with the NDSs. Some nurses estimated that they sit at the computer from one to two hours during their work shift. (Paper II)

6.5 Patient Information Exchange between Healthcare Units

Currently, a lot of clinical and patient data are documented and stored in an electronic format. However, the utilisation of these data during clinical work appears problematic.

Positive and negative results were reported in the questionnaire regarding the clinical ICT systems' abilities with respect to supporting information exchange. Physicians were satisfied with the laboratory results; on the other hand, half of the respondents disagreed with the statements on accessibility and availability of nursing information and patient medical information during clinical work (Table VII). Notably, results were negative in response to statements on accessibility and delivery of patient information between healthcare organisations. Of all respondents, 85% disagreed with the statement 'information about the patient's medication from other organisations is easily accessible'. Likewise, problems related to time taken up by exchange of information between institutions were a critical issue.

Table VII. Example of questionnaire results: physicians' responses to statements about ICT support for information exchange. (Paper IV)

Statements	Strongly agree %	Agree %	Neutral opinion %	Disagree %	Strongly disagree %
ICT support for information exchange					
Information about the laboratory results is presented in a logical format.	14	50	15	15	6
Nursing information is easily accessible and readable.	5	28	14	27	21
Patient's medication list is clearly presented.	3	17	13	22	24
Information about the patient's medication from other organisations is easily accessible.	1	4	9	25	60
Delivery of patient information from other healthcare organisations often takes too much time.	46	28	12	8	6

6.6 ICT Support for Collaborative Care

The questionnaire results are mixed with reference to the quality of IT support for communication. Physicians are rather satisfied with computer-supported collaborative activities between physicians working in the same organisation (Table VIII). In contrast, the findings on computer-supported collaboration between physicians and nurses showed concerning results. Of all the respondents, 43% either agreed or strongly agreed with the statement regarding whether IT supported physician-nurse collaboration. Responses to the statements on ICT-supported interaction between physicians and patients showed that, at present, the use of information systems takes time away from and even disturbs direct patient contact. (Paper IV)

Table VIII. Example of questionnaire results: physicians' responses to statements about ICT support for collaboration. (Paper IV)

Statements	Strongly agree %	Agree %	Neutral opinion %	Disagree %	Strongly disagree %
ICT systems support collaborative activities among physicians working in the same organisation.	14	50	17	14	5
ICT systems support collaboration between physicians and nurses.	6	37	23	25	9
ICT systems help to monitor reception of orders and instructions I have given to nurses. *	1	6	14	16	24
ICT systems support collaboration between physicians and patients.	2	12	31	28	28
ICT systems often capture attention away from patients.	24	40	14	18	4

* 39% of the respondents reported being short of this functionality.

Problems in ICT support of nurse-physician collaborations were also emphasised in nursing documentation system studies. Documented information should be easily accessible and readable for all healthcare professionals involved in patient care. In the present study, nurses had a difficult time when trying to search for and find information in documentation systems. Nurses also claimed that physicians experience even more significant problems and, furthermore, that these problems make physicians unwilling to use the systems or read the documented patient information. In some healthcare units involved in the study, the nurses felt that physicians were set against the use of electronic NDSs for documentation. (Paper II)

6.7 Physicians' Experiences of Participation in Healthcare ICT Development

One of the research topics in the national questionnaire study was physicians' experiences with participation in healthcare ICT development. The results showed strong dissatisfaction among physicians concerning their ability to have an impact on system development (Figure 6). In addition, physicians are disappointed with the ability of IT system providers to produce corrections and changes rapidly and in a desired manner. On the other hand, the results noted significant differences between EHR systems providers. Further analysis also showed variances among the responses from physicians working in public hospitals, healthcare centres, and private provider organizations. For example, approximately half of the physicians in healthcare centres agreed with the first statement ("*When I want to give feedback, I know to whom and how I can send it*.") about knowing to whom and how to provide IT related feedback (50.1%), as compared to 42.1% of their colleagues in private provider organizations and only 36.5% in public hospitals. (Paper V)

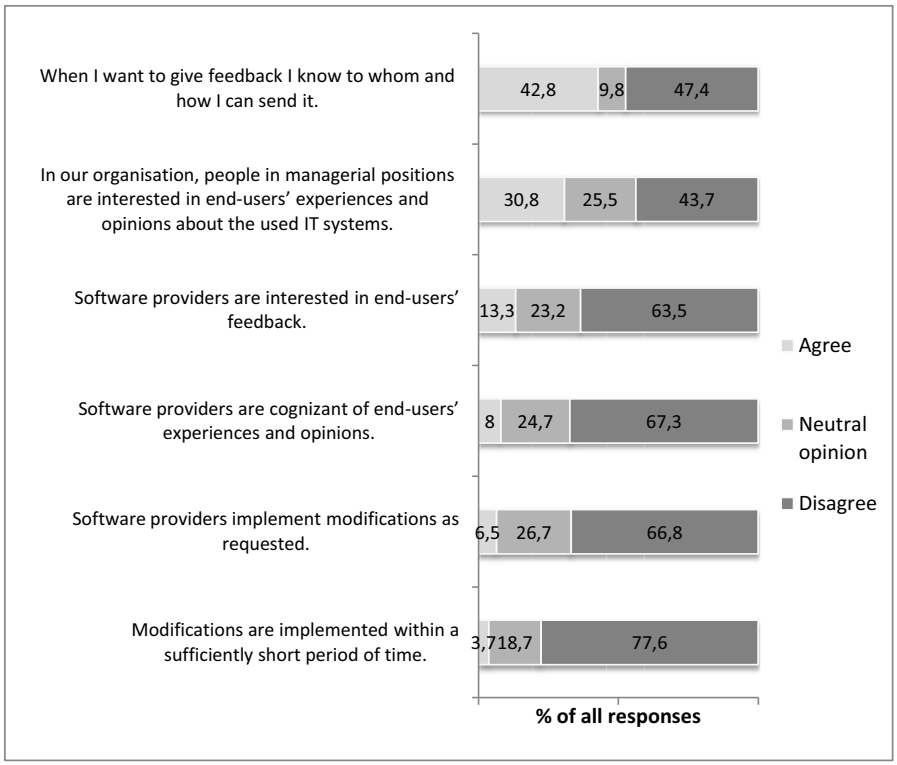


Figure 6. Physicians' answers to statements concerning the provision of feedback to managers and software providers, and their satisfaction with software providers' work regarding IT system development. (Paper V)

6.8 Physicians' Interest in Contributing to Healthcare ICT Development

On the positive side, the questionnaire study indicated that a significant number of physicians who responded to the questionnaire are interested in participating in the development of IT systems in order to achieve better IT tools for supporting their work and clinical tasks (Figure 7). More than half of the respondents (N=2051, 52.2% of all respondents in the study) would be interested in sharing and discussing their experiences with a colleague who had been named as a person responsible for collaborative activities between the end-user organization and the software provider. A significant amount of physicians (37.6% of all 3929 respondents) also expressed their interest in introducing their work to software developers or providers (N=1477) and providing direct feedback by email (N=1159). Furthermore, physicians also supported the idea of a web-based feedback forum (N=731) and a group of end-user representatives that would contribute to the development of such systems (N=608). Only 649 (17.3%) of the 3,741 physicians who responded to this question were not interested in taking part in development activities. (Paper V)

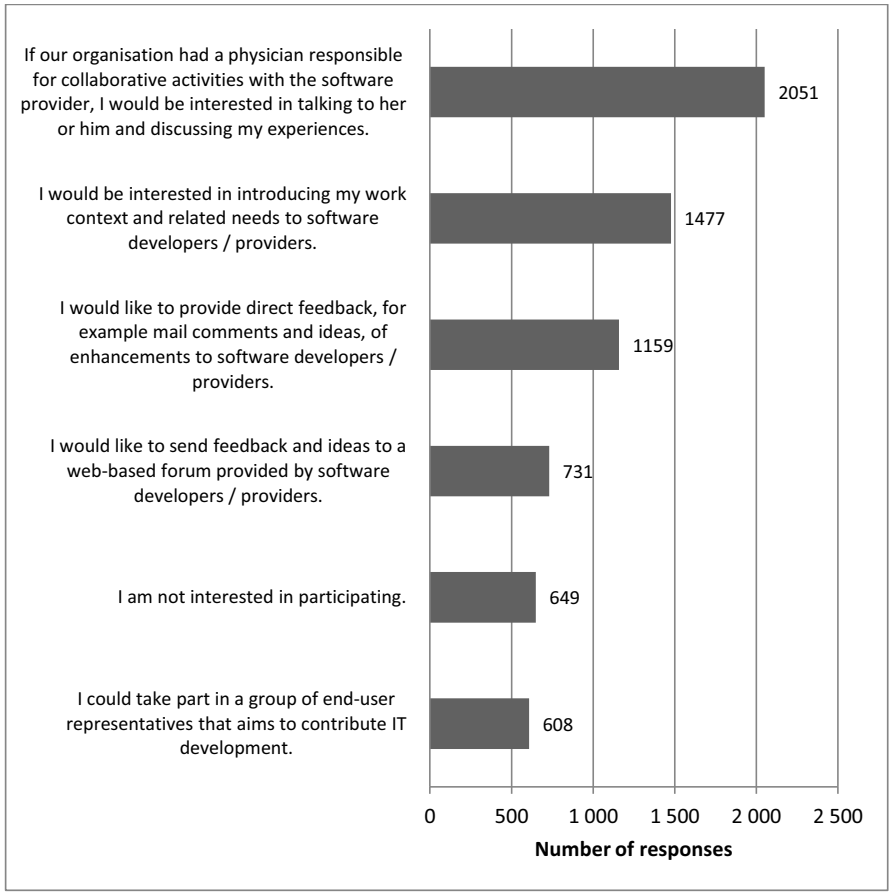


Figure 7. Physician responses to the question concerning their preferred ways of participating in and contributing to healthcare IT development. (Paper V)

In addition, 106 physicians answered that they were interested in participating in IT development activities in some other way than the suggested ones. The analysis of the written answers to the question "How?" resulted in the following findings (Paper V):

- "I have tried to contribute to the development, but have already given up; I used to be interested but not anymore", N=40
- Giving feedback directly to software developers and providers, N= 6
- "I am currently giving feedback to developers", N=5
- Answering these types of questionnaires, N=5
- "I would like to contribute to the development on a national level", N= 4
- Whatever ways that would work, N= 4
- Working as a hired specialist in a development group, N= 4
- Taking part in piloting and evaluating activities organized by providers, N= 3
- Sharing information in discussion sessions in my own organization, N=2.

7 ANALYSIS

This chapter presents the analysis of the study results. The analysis includes three themes:

- *Suggestion for improvements* based on empirical study results. The improvements include five themes: development of efficient and mobile documentation solutions, redesign of EHR user interfaces to streamline interaction sequences, ICT solutions to support communication and collaboration, customisable and context-specific IT systems, and conceptual redesign of nursing documentation system.
- *Three perspectives on clinical ICT usability*, which describes how usability was conceptualised in empirical studies and what kind of aspect the usability approach to designing studies and analysing results was determined to cover.
- *Experiences with UCD methods:* summary of lessons learned with contextual inquiry, tailored usability questionnaire, and interaction sequence illustration analysis methods when applied in the context of clinical ICT system research.

7.1 Towards Usable Clinical ICT Systems: Suggestions for Improvements

The empirical study results (presented in chapter 6) suggested extensive improvements in order for the systems to fit for various working contexts. These are described in the following sections.

Development of Efficient and Mobile Documentation Solutions

Currently, documentation work occupies a significant amount of time during physicians' and nurses' shifts and requires clinicians to follow the procedures determined by information systems. The following scenarios (Figure 9) illustrate the mismatch between clinicians' practices and current documentation solutions. The scenarios are created on the basis of a digital dictation study (Paper I) and a nursing documentation system study (Paper II).

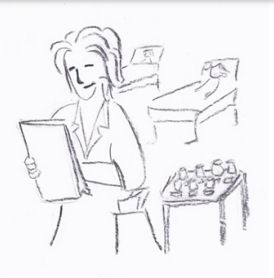
The aforementioned findings and related analysis suggest the urgent need for adapting digital applications so that they better support physicians' and nurses' preferred ways of documentation and information retrieval, and their overall models of action. During the dictation study (Paper I), some of the interviewed physicians asked for portable dictation solutions that would enable them to dictate in the intervals between visiting the patients on the ward. All of the physicians shared the importance of finishing the dictations as rapidly as possible without the need for gratuitous approvals. In general, the voice-recognition technique and mobility were seen as key features for future dictation solutions. Nevertheless, physicians expressed critical opinions when asked about utilising mobile phones for dictation. They argued that the phone cannot be fully allocated for dictation in the case of emergency calls.

In the ward, the physician dictates the patient information after visiting all the patients based on the notes written on paper and the previous patient files. The computer applications do not provide the physician a patient-centred view of all information, instead the physician needs to open multiple applications, search for patient information, and read paper records. The physician instead needs to open multiple applications, search for patient information, and read paper records. The procedure for digital dictation includes a lot of clicking and typically the recording is paused several times.

The converted dictation (from voice to text) is typically returned to the physician for approval within a few days. The physician needs to remember to look for converted dictations from her or his personal electronic checklist. When reviewing and confirming the dictation, the physician needs to recall the patient in order to check the transcribed dictation and make any necessary corrections. What is more, the approval process includes lots of clicking; as was described in Paper II, 26 interaction steps are necessary. Physicians do not type dictations, even though this would allow them to avoid the separate approval phase. The reason for this is the complicated procedure of typing dictation: usability problems in EHR systems; and lack of spelling or other proofing tools.

During rounds, nurses utilise printed patient information and make notes on nursing activities and patients' situations.

Typically, all patient data are documented at the end of a shift. The nurses feel that it is important to document all the data so that nurses during the next shift are able to receive all recent information about the patient's situation.



According to the nurses studied, this documentation work takes approximately one to two hours in time during each shift. The physicians are not willing to use the documentation nurses put into their NDSs. Therefore, the physicians often prefer face-to-face communication and discussion about patients' situations with nurses. In some wards, the most urgent and important messages between nurses and patients are delivered using a notebook.

Figure 9. Scenarios illustrating mismatch between documentation systems and clinicians' practices.

The user requirements for dictation (described in Paper I) can be used to support the development of new dictation solutions. In addition, the observed dictation process, which utilises a voice-recognition system, seemed well suited to the context of use in radiology. The questions raised include: What would an alternative procedure for conducting digital dictation be like? How could the advantages of the observed radiology dictation process be exploited when developing digital dictation and designing concepts of portable documentation solutions?

Based on the previous scenarios and analysis of results, the following improvements are suggested to guide further development of documentation solutions:

- As indicated in the user requirements (Paper I), the dictation solution should be simple, easy to use, and have easy-to-access key functionalities.
- Clinical IT systems should provide intelligent support for documentation and typing. The clinicians should be able to utilise copy and paste functionalities and context-specific templates for cases where the patient profiles and documentation contents are likely to be similar.
- Mobile dictation solutions could support notetaking and documentation during patient visiting rounds in wards. Afterwards, the clinicians should be able to complement the documentation and save the information into EHR system.
- Information systems should provide clinicians a patient-centred view on their earlier records without a need to open and search patient information from multiple applications based on social security number. These records should be easily accessible; for example, the EHR system should automatically offer the clinicians a list of patients currently in the ward and enable them to select the right one from these.
- The possibilities of utilising voice-recognition technique in documentation should be carefully considered. Based on the digital dictation study, the technique had several advantages when compared to digital dictation, e.g. the process does not include conversion and approval phases, and it enables the users to perceive the dictation as a whole while dictating.
- Clinical IT systems should better support information exchange between physicians and nurses. EHR and nursing documentation systems should include functionality (text area in an individual patient's record) for delivering important messages or observations.

Redesign of EHR User Interfaces to Streamline Interaction Sequences

Studies on nursing documentation systems and digital dictation procedure showed that a significant number of problems that surface during use of clinical IT systems derive from poor usability and insufficiencies in interaction design. The digital dictation procedure was shown to consist of nine interaction stages and include over 60 interaction steps (Paper VI). As illustrated by the nursing documentation system study, the complexity of the user interface design can reflect poorly on the ease of learning the system, and on whether the system is intuitive to use. Complexity can easily cause nurses to make errors when entering nursing documentation, and learning how to document fluently with the system may even take several years (Paper II). Furthermore, findings from the questionnaire study showed that lack on integration between the systems, technical problems, and system failures hinder clinical work.

Redesign of the user interface for EHRs (and NDSs) with overly complex interfaces could help to overcome these problems and decrease the user's feelings on disintegrated IT systems. For example, guidance on where the information will be found, how to access other systems, and appropriate feedback on users' actions as well as on those actions the system is performing would help the user manage complex situations and the use of multiple systems. However, when redesigning the user interfaces the developers should consider the systems as integrated parts of a larger technology environment and approach the issues of system usage from the perspective of the end user in order to identify and understand the user's needs and requirements. The empirical studies also indicated that several of the observed usability problems in EHR user interfaces could have been easily improved and avoided by following the general usability design guidelines.

ICT Solutions to Support Communication and Collaboration

Overall, the current clinical IT systems seem to prioritise data storage and documentation over the facilitation of communication and collaboration between clinicians. The large number of disparate information systems and the non-integrated information technology infrastructure hinder the efficiency of clinical work and patient information exchange between units and healthcare organisations. Nurses have also indicated that clinicians' dissatisfaction with IT systems may even disturb collaboration between healthcare professionals, as physicians are not willing to look for patient information and nursing documentation from the NDSs. Physicians indicated that they found the NDSs time-consuming to use and contents of the nursing documentation difficult to read. Furthermore, findings from the national questionnaire study suggested that communication applications and mobile or wireless solutions have not been widely adopted in Finnish healthcare organisations.

New communication solutions are needed to better support collaboration between clinicians within and between organisations. For example, new functionalities to support collaboration and delivery of messages could be integrated into health record systems. EHRs and NDSs should support delivery of important messages between physicians and nurses, particularly in the wards. Clinicians should be able to deliver and receive important messages using electronic notes attached in patient records. With these electronic notes, when a clinician opened up the patient record he or she would immediately notice a new message and be able to mark the message as having been read, after which confirmation would be automatically forwarded to the sender.

The new solutions should also support collaboration and interaction between clinicians and patients. At present, patients have very limited access to their own health information. Possibilities for utilising electronic channels when communicating with healthcare professionals are even more limited. Due to problems in cross-organisational information exchange, patients are required to keep track of their own medical information. For example, a trustworthy electronic communication channel for patient-physician communication and an application enabling information exchange between patients with chronic illnesses or conditions (or chronic injuries) and healthcare workers would allow patients to take a more active role in their own care. These kinds of changes in responsibilities and roles would, however, require careful consideration.

Customisable and Context-Specific IT Systems

Some of the reasons behind the needed improvements derive from contextual issues – the current solutions are not suitable for use in all the healthcare contexts in which they are currently being employed.

Results from the questionnaire study indicated that physicians working in public hospitals seemed to be more critical of IT systems and these systems' abilities to provide support for routine tasks in comparison to their colleagues in healthcare centres (Paper IV). Likewise, in the nursing study, nurses working in wards and clinics had different kinds of needs from a documentation solution, and different context-dependent practices. Table IX describes the characteristics of nursing work in wards and in clinics, and thereby suggests that the starting points are different for NDSs arising from contextual aspects of clinical work. These findings are based on the NDS study (Paper II), which applied a contextual inquiry method to explore users' needs during work in various types of healthcare units. For example, in wards nurses typically utilise a nursing plan when documenting daily entries; in contrast, in clinics it is important to deliver information about the activities conducted with a patient as soon as possible to other professionals after patient appointments.

Table IX. Characteristics of nursing work in clinics and wards (Nykänen et al., 2010).

Clinic	Ward
Clinics have high patient turnover. On the other hand, the profiles of the patients are often similar (e.g. asthma patients in control visits). Compared to nursing documentation produced in wards, the content of documentation in clinics is simpler. The nurse aims at delivering the patient data to others involved in care as soon as possible after the patient leaves the appointment. Patient data is documented (input) in the correct electronic systems right after appointments. The structured nursing documentation model covers three phases: planning, action and evaluation. In clinics the documented information is typically related as the 'action' phase. The nurses are not willing to document 'planning' and 'evaluation' related nursing information. They feel that following the model is not well-suited to the practical work and to the information needs of other clinicians who provide care.	Wards can provide either short-term or long-term care, depending on the speciality of the ward. When patients arrive at wards, the nurses document a care plan, which forms the basis for documentation during the caring period (documentation entries describing actions, progress, or evaluation). A well-documented and detailed plan supports further documentation work. The plan is updated as the period of patient care proceeds. At the beginning of the shift the nurses read the documentation written by their colleagues during the previous shift. Most of the electronic documentation work is conducted within the later hours of the shift. Between shifts communication is reliant on documented patient information and nursing documentation systems. It is important that all the latest information about the patients is available for the nurses starting work during the next shift. Communication and information delivery between nurses and physicians is important for the sake of continuity of care.

Currently, implementations of nursing documentation systems do not support contextual aspects of nursing work or tailoring of the systems to meet the needs of clinical units or nurses' individual preferences. Therefore, clinical IT systems need extensive improvements and redesign in order to fit various working contexts and support clinical tasks that are different according to clinical unit (e.g. in clinics and in wards).

When developing and redesigning healthcare ICT systems, it should be noted that clinical environments in which the solutions are used can vary considerably, and the same solution is not suitable for all clinical contexts. The development work should pay attention to differences between clinical contexts and the users' needs and requirements towards ICT systems, instead of forcing clinicians to adjust their practices and procedures to the prevailing technical environment or to hospital-wide comprehensive systems. Therefore, it is important to consider how to provide the end-users customisable user interfaces or make it possible for the managers of the healthcare units and organisations to modify the general solutions to fit the organisational surroundings.

Conceptual Redesign of Nursing Documentation Systems

The study with nurses showed that usability problems in NDSs adversely affect the documentation practices and nursing and care work of nurses. All of the systems evaluated share similar general usability problems, although the evaluations for the implementation of individual nursing documentation models and their related user interfaces were considerably different. The following figure (Figure 10) depicts a

reconstructed version of a nursing documentation system interface. The figure was drawn after the empirical study to visualise the main components of a structured nursing documentation model (Nykänen et al., 2011a). As such, the figure does not illustrate any of the currently used systems, or represent a redesigned concept of NDS.

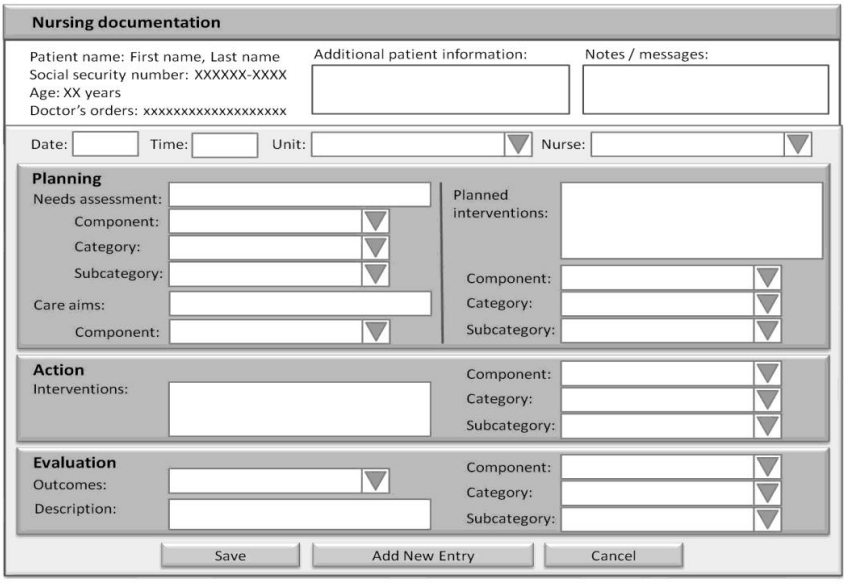


Figure 10. A reconstructed version of a NDS user interface. The interface illustrates the basic components of nursing documentation systems and the structure of a documentation model.

Based on the findings, the concept of the NDS should be redesigned. Redesign should particularly focus on the following aspects: increased accessibility and readability of documented patient information, intuitiveness of system use, and reduction of unnecessary interaction steps. For example, the complicated sequences of structured documentation and selection of classifications cannot be overcome only by redesigning the user interfaces. The evaluated systems also poorly supported the use of structured templates or copy functionality, although the contents of patient documentation within a clinic or a ward typically follow the same structure. Instead, the systems should provide the nurses intelligent support for documentation and enable them to proceed in a bottom-to-top fashion when using the classifications (meaning that the nurses would be able to select the third-level classification, representing the most concrete components, from the three-layer model, and the system would automatically show what the related two higher level classifications are, and provide the nurse a possibility to select these). The qualitative study results and the described usability criteria for nursing documentation system evaluation can be used to guide further development of the documentation systems, in particular determination of user requirements and conceptual redesign.

7.2 Three Perspectives on Clinical ICT Usability

In the HCI literature, usability is described as being a contextual property (ISO 9241-11, 1998; Nielsen, 1993; ISO 9241-210, 2010), meaning that usability should always be defined and measured in relation to a specific context of use. A widely-known definition for usability, presented by ISO 9241-11 standard (1998), describes 'usability' and the components of 'context of use' as follows:

> *Usability is the extent to which a system can be used by specific users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.*

The definition indicates that usability is not only a characteristic of a user interface, but instead, covers issues ranging from emotional and temporal dimensions to user goals. In addition, the definition emphasises the relation between usability and context of use: usability does not exist in any absolute sense, and it can only be defined with reference to a particular context (ISO 9241-11, 1998). Understanding the context of use characteristics is important also from the viewpoint of interactive system design: the first activity in the iterative cycle of human-centred design process is named as 'understand and specify the context of use'. The context of use of a system should be described in sufficient detail to support design and evaluation activities, including specification of usability requirements and objectives (ISO 9241-210, 2010).

The literature review on usability-related research indicated that the contextual nature and the applicability of the definition of 'usability' to fit in the health informatics domain seem to be poorly understood and inadequately addressed by researchers and practitioners. Often, the objectives of evaluation studies are expressed as a list of adjectives, e.g. referring to the key attributes, such as learnability and error prevention, described by Nielsen (1993). These attributes do not reflect the contextual aspects behind the study – the characteristics of clinical work and the goals the users aim to achieve when using clinical ICT tools. Furthermore, articles on system evaluation or development do not describe the characteristics of the healthcare context (according to the ISO 9241-11 standard (1996) usability should be understood as a contextual property) or the components of the context of use (according to the same standard, the components of the context of use are: user, tasks, equipment, and environment).

In the described three empirical studies, special attention was paid to understand the characteristics of the context of use when designing the studies: setting up the usability criteria for the evaluation of NDSs and designing questionnaire items for the national questionnaire study. In these studies, the researchers conducted the work together with clinicians that are experts in the medical and nursing fields. In contrast to these two, the dictation study aimed to gather data for the purposes of creating an understanding of the context of use characteristics, and was based on studies describing user and usability requirements for future dictation solutions. As a result, the following three perspectives on clinical ICT usability were described. These perspectives reflect clinicians' viewpoints on technology use and the characteristics of clinical work; e.g. aspects of communication and collaboration.

Perspective 1: Usability dimensions of clinical ICT environments from the physicians' viewpoint (Paper IV)

Compared to typical usability questionnaires such as the System Usability Scale (SUS) (Brooke, 1996) or the Software Usability Measurement Inventory (SUMI) (Kirakowski, 1994), the idea behind the national questionnaire study was to research the usability of EHR systems and other clinical ICT systems from a broad perspective and include the specific topics for the questionnaire context. For the purposes of the study, the following

description including three usability dimensions was described (Figure 8) (Paper IV). The dimensions emphasise the characteristics of a physician's work in clinical surroundings, and approach usability from the viewpoint of the end-users experiences in the context of using numerous clinical ICT systems.

The usability of clinical ICT systems refers to the ability of the systems to have a positive impact on patient care by supporting physicians in achieving their goals with a pleasant user experience. In order to support physicians in their daily clinical work, ***ICT systems need to be compatible with physicians' tasks (dimension 1)****. In a more concrete level, this indicates that the systems should provide the physicians with key (context-matching) functionalities, be efficient (especially in terms of record-keeping and information retrieval), and have intuitive user interfaces.*

In addition, ***ICT systems should support information exchange, communication and collaboration in clinical work (dimension 2)*** *and be* ***interoperable and reliable (dimension 3)****. Since the clinical ICT systems are used in numerous environments, they should also adjust to various user needs and organizational settings.*

Figure 8. Description of the usability aspects of clinical ICT systems from the perspective of physicians. (Paper IV)

The objective of describing the dimensions was to build an understanding of key dimensions and attributes of clinical ICT usability when observed from the viewpoint of physicians. Thereby, the description grounded the design and analysis of the usability questions in the empirical study. The dimensions are derived from the definitions of usability and the clinical context of use analysis, and they reflect the ability of ICT systems to have a positive impact on patient care by supporting physicians in achieving their goals with a pleasant user experience. The themes of usability questions and statements are presented in detail in paper IV.

Perspective 2: Usability criteria for the evaluation of nursing documentation systems (Paper II)

The usability criteria (presented in Table X) for the evaluation of NDSs were applied and validated in the empirical evaluation study that incorporated four documentation systems (Paper II). The criteria were constructed based on the characteristics of nursing work. The work utilised the definitions of usability by Nielsen (1993) and the ISO 9241-11 standard (1998). The idea was to describe the contextual attributes to guide the evaluation of the nursing model and its implementations.

The criteria include five of the most apparent usability attributes that illustrate the objectives the nurses have as system end-users. In Table X, 'aspects of interest' describe the five usability attributes at a more detailed level, e.g. in the study, the attribute of '*usefulness of the documented information*' was to cover issues of exploitation of documented information by nurses: how the use of NDS (a) supports the nurse's work and the exchange of information between the nurse and other clinicians, as well as to gauge (b) if the manner of representation of information in the NDS is suitable from the nurse's perspective. The criteria were used when designing the themes for contextual inquiries and when analysing the results. Also, the reporting of the results was conducted following the usability attributes. Thereby, the results (presented in paper II) provide more information about the content of usability attributes and the aspects they were seen to cover in this particular evaluation study.

Table X. Usability criteria for the evaluation of nursing documentation systems: five usability attributes and related aspects of interests (Paper II).

Usability evaluation criteria	Aspects of interest
Fluency of the documentation	Efficiency and effectiveness of production of documentation, simplicity of the system, ease of use
Accuracy and correctness of the documentation	Errors in the performance of the documentation, system support in failure protections and recovery
Learnability of the system	Intuitiveness of use, the ability of the system to guide new users
Usefulness of the documented information	Exploitation of documented information by the nurses: support of the nurse's work, exchange of information, manner of representation (content and layout)
Collaborative use of the documented information	Support communication and collaboration between nurses and other health professionals: accessibility and readability of documented information, information exchange, and manner of representation compared to multi-professional needs

Perspective 3: User and usability requirements for a dictation solution (Paper I)

In the dictation study, the seven user requirements (presented in Table XI) for an adequate dictation solution were described based on the analysis of contextual inquiry results to demonstrate the dictation process from the physicians' viewpoint and illustrate the identified user needs and constraints for the redesign of documentation solutions. In the study, these requirements were also used as criteria for evaluating the currently used dictation techniques. The requirements are described in more detail in Paper I.

The requirements reflect several contexts of use characteristics. For example, the dictations are often conducted in environments in which other people are present. Therefore, the dictation solution should support silent, independent working (requirement 6) even in crowded, noisy surroundings (e.g. in emergency departments). In the wards, the physicians are willing to dictate at any opportune moment, meaning that in the afternoon, after patient rounds, it might be difficult to recall all the patient information. Often physicians rely on their paper notes. The dictation solutions should provide physicians with a flexible opportunity to dictate (requirement 1), e.g. in the middle of the round before entering the new patient room. The observed digital dictation solutions were integrated together with EHR systems, meaning that the physician needs to conduct the dictation in his or her office. From the viewpoint of designing new mobile and portable dictation solutions, the seven described requirements can be used as starting points for describing the high level user requirements and reflecting the aspects of usability which are important to be considered from the solution end-user viewpoint in the evaluation phases.

Table XI. Seven user requirements for a dictation solution. (Paper I)

User requirements for a dictation solution
1. The physician should be able to dictate at any opportune moment.
2. While dictating, the physician needs to have access to various patient information resources (e.g. in wards laboratory results, nursing documentation, and previous patient documentation in EHR).
3. The dictation solution should be simple and easy to use.
4. The dictation solution should tolerate prolonged pauses.
5. While dictating, the physicians should be able to perceive the contents of dictation as a whole in order to structure the text in a meaningful way and include all the necessary information.
6. The dictation solution should support silent, independent working.
7. The dictation process and solution should fit the intended context of use. For example, in wards, clinics, and emergency departments, the situations and surroundings in which the dictations are conducted vary greatly and the need for urgency of exchanging information through dictated messages is different.

To summarise, experiences from the empirical studies emphasised the need for understanding usability as a contextual property – meaning that the objectives of usability studies should reflect the characteristics of the contexts of use in which the interactive systems are used. The work of describing the usability perspectives derives from the understanding of the context of use components. Therefore, this understanding forms the basis for planning usability evaluation studies, describing usability attributes and dimensions, as well as for eliciting user and usability requirements for system design.

7.3 Experiences with UCD Methods

Experiences from three empirical studies suggested that the applied methods – particularly contextual inquiry, tailored usability questionnaire, and interaction sequence illustration analysis – have several advantages and challenges when employed in clinical contexts. The empirical studies also indicated that the clinical IT systems need to be closely integrated into the surrounding technology environment (that is, from the users' perspective). Users must employ many different types of clinical IT systems in concert, and evaluating each system independent of the others would not be useful. Based on the digital dictation and nursing documentation system studies, access to real environments in which clinical IT systems are used is crucial in order to gather reliable and rich data for research and development purposes. The following table (Table XII) summarises the experiences and lessons learned through the methods of contextual inquiry, interaction sequence analysis, and the tailored usability questionnaire.

Table XII. Summary of advantages and challenges of applying UCD methods in the context of clinical ICT system research - lessons learned through contextual inquiry, interaction sequence illustration analysis, and the tailored usability questionnaire. (Papers I, III-VI)

Advantages	Challenges
Contextual inquiry (Papers I, III, and VI)	
• Addresses the issues of clinical IT system usage from end-user and task-oriented perspectives (versus system-centred evaluation). • Enables the researchers to make insightful observations and inquire about clinicians' actions. • Provides the researchers an opportunity to increase their understanding of the domains of healthcare technology and medical practice. • Enables the gathering of large amount of qualitative data that can be used for several purposes, including the contextual issues around healthcare IT use; to find out user's needs and wishes concerning improvements. • Provides concrete data about usage of IT systems in clinical settings: interaction between the user and the systems, effectiveness of use, communication and information-sharing aspects.	• Requires access to real clinical settings and permission for recording. • Requires clinicians' participation – clinicians tend to be busy while working in a hectic, fast-paced environment requiring critical care for patients. • Potentially time-consuming due to the highly qualitative nature of the method. • Issues of recording of medical and patient data, patient privacy and health data security must be considered. All recorded data needs to be carefully anonymised. • The representativeness of the data is easy to question since studies usually have a small number of enrolees (users per user group). In other words, when the total number of involved users is small, how does this account for the wide variety of clinical practices and contexts for technology use?
Tailored usability questionnaire (Papers IV and V)	
• Researchers: A suitable technique for gathering information from a large group of users. Provides the possibility to inquire about numerous themes related to IT use from various viewpoints. Easy to reach a high number of desired respondents when performed via a web-based format. • System end-users: Web-based questionnaires are easily accessible and provide a means for giving feedback about IT usage-related issues anonymously. • Reports subjective experiences (direct clinical response) with IT usage. • Typically produces quantitative data, but can also include open-ended questions. Large quantitative data makes it possible to conduct comparative analysis and identify context-specific differences between physicians' responses from various clinical contexts. • Data gathering does not require a lot of resources. • The qualitative approach to interpretation of quantitative results and analysis of open-ended comments may provide means for addressing further development actions. • Provides rich data for comparative analysis (differences between responses from various healthcare units and organisations).	• What aspects of usability are suitable for study using a questionnaire method? In order to support user-centred design, questionnaires should be used in conjunction with other methods. • Designing a questionnaire study is extremely difficult and requires in-depth knowledge about usability research issues as well as about domain-specific characteristics and clinicians' contexts. • Questionnaire items need to be carefully formulated so that they are correct and appropriate from the respondents' point of view. The questionnaire form needs to be carefully pilot-tested and evaluated with potential respondents. • The objectivity of the results can be easily questioned. • How are the validity and reliability of the questionnaire determined when the questionnaire has been designed by the research team? • Low descriptive value: Summative evaluation approach provides general hints to problem areas but is unable to either detect concrete weaknesses or reveal the causes. • Limitations: It was difficult for the respondents to envision the future systems, but easier to describe the present state and ask for changes in it.

Advantages	Challenges
Interaction sequence illustration analysis (Paper VI)	
• Provides concrete and detailed information about the stages and steps of interaction, usability of user interface, effectiveness of use, and the success of interaction design. • Does not necessarily require access to clinical environments, since the method enables remote analysis if the data is captured (for example, by end users). • May provide new opportunities and concrete tools to support collaborative development activities between developers, researchers, and end-users.	• Defining stages of interaction is not a straightforward or a strictly guided process. • Issues of patient privacy and health data security must be considered. All data need to be carefully anonymised by the analysis phase (at the latest). Permission is required to take screenshots. • More work needs to be conducted to understand and to evaluate the ISI method in order to describe the advantages and disadvantages of its use when applied in usability evaluation as well as for the purposes of user interface design and interaction design.

8 ANSWERS TO RESEARCH QUESTIONS AND CONCLUSIONS

The overall goal of the thesis was to gain improved understanding of usability issues and apply a user-centred design (UCD) approach in the health informatics domain to support further development of healthcare technology applications. Thematically, the thesis research included three viewpoints: empirical, conceptual, and methodological. In the following sections, answers to research questions and related conclusions are presented according to these three viewpoints.

8.1 The Empirical Viewpoint

Motivation for the thesis research was derived from the contradictory findings on the practical benefits of healthcare IT adoption and use, and the established need for user-oriented approach to development work. Empirical studies were carried out to examine the current state of clinical IT usability. The national questionnaire study with 3929 respondents provided a generalised picture about the usability of currently used clinical ICT systems from the viewpoint of physicians. Studies of dictation and nursing documentation systems applied the qualitative approach and investigated the use of systems in their real-life surroundings.

The study results (described in chapter 6) provided answers to the first two research questions.

Q1) From the perspective of clinicians, how do the currently used IT systems support their everyday work?

The currently used IT systems do not support the daily work and clinical tasks of clinicians well. The answer to the first question is given in reference to often discussed attributes of usability: *satisfaction*, *efficiency,* and *effectiveness* (ISO 9241-11, 1998).

Satisfaction: Physicians' ratings for their principally used EHR systems were relatively low (chapter 6.1). Their desires for improvements aimed to make these widely and often used clinical IT systems simpler, more reliable, and quicker to use. Likewise, nurses felt dissatisfaction since a good deal of their work time is occupied with the nursing documentation systems (chapter 6.4).

In addition, the following physicians' comments, which are selected from among the open-ended answers given in the questionnaire study (Papers IV and V), describe the current situation (the comments have been translated from Finnish by the author):

> *"I usually do not consider myself a pessimist, but EHR system X has got me on my knees. I hope the glitches are related to the early phases of system use, and those massive errors and deficiencies the system has can be improved. Physicians are forced to serve IT systems, and patients have been sidetracked.*
>
> *"It is surprising that we do not take advantage of the capabilities of IT. Electronic healthcare record (EHR) systems are in many ways "analogue" (different kinds of lists, clicking, things which are not needed in my own area of medical speciality). No increases in efficiency have been achieved; instead, attention has to be paid to the use of the EHR system, not on taking advantages of the medical contents. All the*

time we suffer from slowness. Technical interruptions, of which the help-desk is not aware of, no possibilities for giving feedback or reporting of problems, etc."

Efficiency and effectiveness: The currently used clinical systems do not support the efficiency of the clinicians' work. Physicians in particular expect their systems to provide better support for performing routine tasks than they currently do (chapter 6.3). Users feel that the systems generate additional tasks.

Numerous clinical tasks relate to and rely on information management and clinical documentation. The current clinical IT systems are poorly suited to the requirements of these tasks (chapter 6.2). IT systems also lack key functionalities, such as proper patient overview charts and summaries of previous nursing activities (chapter 6.4). The efficiency and effectiveness of clinical work is also hindered by the lack of computer support for multi-professional and cross-organizational collaboration between clinicians (chapters 6.5 and 6.6). For example, empirical studies showed that nurses had difficulties when trying to search for and find information which has been documented into nursing documentation systems during previous shifts. Similarly, physicians experience that information from other organizations about the patient's medication is not easily accessible.

Q2) What are the critical usability and interaction design-related problems?

Although usability issues were approached from different viewpoints and from different levels of abstraction in the three empirical studies, the studies identified the same kind of critical usability problems.

Current styles of electronic documentation divert significant time and resources from caring and nursing. Documentation requires a lot of time because of poor user interface design, complicated interaction sequences, and non-integrated information systems (chapter 6.2). In addition, information retrieval from the systems is time-consuming.

User interfaces of current systems are characterized by multiplicity of user interface components (chapter 6.3). Nurses in particular had experienced difficulties in learning how to use the nursing documentation systems. Due to the complexity of user interfaces, the systems are not intuitive to use, as they do not guide the users in information processing.

Other interaction design-related problems relate to the following:

- Information is presented in an inappropriate manner (chapters 6.3 and 6.4)
- The systems do not provide clinicians with context-specific information (chapters 6.3 and 6.4)
- The systems do not consider differences between clinical contexts (clinical tasks and clinicians' needs) – the IT solutions are not suitable for use in all healthcare contexts in which they are currently being employed (chapters 6.3 and 6.4). For example, the evaluation of nursing documentation systems revealed that physicians and nurses have similar user interfaces although their information needs in regards to documented nursing information are different.
- Support for patient information exchange and collaboration is insufficient: Information from other organizations is not easily accessible and delivery takes too much time (chapter 6.5). Both nurses and physicians were critical about the currently used nursing documentation systems and ICT support for physician-nurse collaboration (chapter 6.6): the systems do not fit the clinicians' needs — instead of using the documentation systems, nurses and physicians prefer other ways of communication, e.g. face-to-face discussions and delivering messages using pen and paper.

The found usability and interaction design-related problems can have significant effects not only on clinicians' documentation practices but also on clinical work itself. This in turn can have an unplanned effect on patient care, and also in some way reflects the more general attitudes of healthcare professionals with respect to the use of information systems.

The described findings on fluency of documentation and information retrieval are consistent with a number of evaluation studies showing that barriers to healthcare IT use include usability issues and time taken up by clinical documentation and record-keeping (e.g. Poissant et al., 2005; Kjeldskov et al., 2007; Häyrinen et al., 2008). Earlier studies have also found that medical errors can be caused by usability flaws and user interface design problems (Fairbanks and Caplan, 2004) and that these same problems also effect computer-mediated collaboration between healthcare professionals (Horsky et al., 2005).

Q3) How should the identified problems and challenges (Q1 and Q2) be overcome: What kind of improvements do the empirical study findings suggest?

The three studies on usability not only evaluated current systems but also strove to understand how to improve and overcome problems and challenges identified in these. The thesis described five themes related to potential improvements (chapter 7.1).

- Development of efficient and mobile documentation solutions
- Redesign of EHR user interfaces to streamline interaction sequences
- ICT solutions to support communication and collaboration
- Customisable and context-specific IT systems
- Conceptual redesign of nursing documentation systems.

These themes reflect a broad approach to user-centred development of clinical ICT systems and are derived from the previously described usability and interaction design-related problems (answers given to questions 1 and 2).

Summary of the empirical viewpoint. Both the empirical study results and the related suggestions for improvements can be seen to have novelty value, since, as indicated by the literature review, researchers in the fields of health informatics and human-computer interaction (HCI) have not previously applied such a research approach, analysed the characteristics of the clinical context for ICT development purposes, or addressed the needed improvements from such broad perspectives. Thereby, implications for research include empirical exposition of existing usability problems and clinical IT system characteristics that make the systems inferior to others and hinder the efficiency of clinical work by physicians and nurses. Likewise, implications for their design are the identification of the main usability and interaction design problems. The empirical findings and analysis led to the following conclusion:

Poorly designed IT systems hinder the efficiency of clinical work. The currently used clinical IT systems suffer from numerous usability and interaction design-related problems. Based on empirical studies, suggestions for improvements include the following: development of efficient and mobile documentation solutions; redesign of EHR user interfaces to streamline interaction sequences; ICT solutions to support communication and collaboration; customizable and context-specific IT systems; and conceptual redesign of nursing documentation systems.

8.2 The Conceptual Viewpoint

The conceptual viewpoint of the thesis research included two questions.

Q4) What is the scope of usability in the context of clinical IT system research?

The scope of usability in the health informatics field is more restricted than it is in the user-centred design and usability research fields. Review of the literature (chapter 3) showed that in the research domain of health informatics, usability is closely associated with evaluation and testing activities. Furthermore, usability-related research in the field is characterised by the following aspects: *narrow focus on user and usability issues, emphasis on summative evaluation rather than on design or development, isolated system development, and emphasis on information systems and data management instead of on designing systems to support communication and collaboration.* These findings indicate that the scope of usability work needs to be broadened.

Recent studies have already emphasised a more holistic view. For example, Jaspers (2009) and Horsky et al. (2010) argue on behalf of a multi-method approach and its benefits as compared to the use of a single evaluation method. Usability evaluation studies should aim at supporting design and development work, instead of only assessing or judging usability of implemented information systems. As stated in standard ISO 9241-210 (2010), user-centred evaluation should aim at "collecting new information about user needs, providing feedback on strengths and weaknesses of the design solutions from the user's perspective, assessing whether user requirements have been achieved, and establishing baselines or making comparisons between design". With references to this comment, it would be important to understand that usability cannot only be evaluated but it can also be addressed during development work as is stated in the ISO 13407 standard (1999): User-centred design (UCD) is an approach to interactive system design and development that focuses specifically on making systems usable. Moreover, the standard (ISO 13407, 1999; ISO 9241-210, 2010) defines four activities of the iterative development process. In addition to evaluation, these include description of the context of use, specification of user requirements, and production of design solutions.

Another viewpoint that arose from the literature review was the lack of understanding of a) the contextual aspects of usability, and b) the characteristics of clinical work contexts. The widely known definitions for usability (e.g. by Nielsen and by the ISO 9241-11 standard) emphasise the need to understand usability as a contextual property. The definitions also indicate that usability can be addressed from several intersecting perspectives – for example, one perspective that focuses on the characteristics of a user interface and the immediate interaction between a user and a system, and another perspective that considers issues deriving from the components and characteristics of the context of use. These perspectives are easy to agree with, since from a development perspective, usability work should aim at designing systems that help users achieve their desired goals.

Q5) What are the specific aspects that should be addressed when studying usability of clinical ICT systems in healthcare contexts?

In the empirical studies, usability aspects were addressed from the viewpoints of physicians and nurses. The studies showed that usability is extremely context-sensitive by nature – even the usability of a single system has different attributes depending on end-user groups. For example, nurses utilize NDSs for different purposes than physicians and therefore the criteria of usability are different. On the other hand, the empirical studies

suggested that the contexts of clinical work are diverse. The following figure (Figure 11) and the related description illustrates this diversity and the multiplicity.

Generally speaking, the context of clinical work is characterised by a hectic atmosphere, an ever-changing working environment, altering practices, a diversity of technology applications, and heterogeneous healthcare staff with various skills and experiences. The aim of clinical work is to take care of and cure patients. Although clinicians share this work objective, individuals in healthcare organisations have different responsibilities in work, diverse and dynamic working practices, and numerous communication and interaction routines. Physicians and nurses are the *primary users* of the clinical ICT applications. The *technical environment* in healthcare organisations consists of thousands of information systems, medical devices, and other technology applications. The *surroundings* in which clinical ICT systems are used vary from outpatient to inpatient environments in public and private sector organisations, hospitals and healthcare centres, and a range of healthcare units with a number of fields of specialisation. Moreover, numerous types of units inside healthcare organisations (wards, operation rooms, control rooms, emergency rooms, clinics, etc.) have special characteristics when physical, organisational (including organisational structure, rules and division of work), and social (such as cultural models and attitudes) aspects are considered.

Figure 11. Illustration of variety of clinical working contexts.

The work describing three *conceptualisations for usability of clinical ICT systems* (chapter 7.2) aimed to increase the understanding of contextual aspects of usability in healthcare settings for the purposes of usability research and system development. The three perspectives were the following:

1) Usability dimensions of clinical ICT environments from the physicians' viewpoint: ICT systems need to be compatible with physicians' tasks; ICT systems should support information exchange, communication, and collaboration in clinical work; ICT systems should be interoperable and reliable. (The dimensions were described for the purposes of a tailored questionnaire study and are presented in detail in Paper IV.)
2) Usability criteria for the evaluation of nursing documentation systems: Fluency of the documentation; accuracy and correctness of the documentation; learnability of the system; usefulness of the documented information; collaborative use of the documented information. (The criteria and included usability attributes were described for the purposes of evaluation of four nursing documentation systems and are presented in detail in Paper II).
3) User requirements (from a physician's perspective) for a usable dictation solution: 1. the physician should be able to dictate at any opportune moment; 2.while dictating, the physician needs to have access to various patient information resources; 3. the dictation solution should be simple and easy to use; 4. the dictation solution should tolerate prolonged pauses; 5. while dictating, the physicians should be able to perceive the contents of dictation as a whole in order to structure the text in a meaningful way and include all the necessary information; 6. the dictation solution should support silent, independent working; 7. the dictation process and solution should fit the intended context of use. (The requirements were described based on the digital dictation study and are presented in detail in Paper I.)

The theoretical background of the work originated from a usability research of the literature, particularly from widely known definitions of usability and an analysis of context of use characteristics. Moreover, the results of the empirical studies (chapters 6.1 to 6.8) reflect a broad approach to usability work and emphasise *contextual aspects that are specific for clinical contexts*. Together with the three perspectives on clinical ICT usability (presented in chapter 7.2), these results suggest the following usability principles for clinical ICT systems:

1. Consider ICT systems as part of the wider technology environment.
2. Understand the contextual requirements, derived from the characteristics of clinical work: the essential role played by patient information management, the high degree of communication and collaboration necessary among professionals, and the diverse and dynamic working practices of different healthcare organisations and different clinical contexts.
3. Pay attention to the divergence of use contexts, end-user groups and contextual requirements for systems use.

These suggestions are supported by Randell et al. (2010), who have recently stated that in evaluating new interactions in healthcare 'there is the challenge of understanding how new healthcare technologies become integrated with other existing technologies and the impact of increasingly complex technological arrangements, rather than just focusing on the single new system'.

The understanding of contextual aspects can guide user-centred evaluation and redesign activities, support the design of usability studies, and inform designers and developers about user and usability requirements for clinical ICT systems. What is more, a broader

view and contextual approach on usability can help understand and cope with the ongoing changes in healthcare ICT adoption and use. In the near future, the emerging aspects of collaboration and patient-centred care in clinical work (as described in chapter 2.2) will raise even more concerns for traditional considerations of usability and evaluation assessment, and indicate the need for shifting the focus from a single system evaluation to broader aspects, e.g. communication and collaboration. In order to support the development and redesign of current clinical IT systems, usability work should aim at identifying the current problems, understanding the reasoning that informs the perspective of end-users, and describe how clinical IT systems should be improved – in other words, redesign the systems in a way high usability is achieved.

8.3 The Methodological Viewpoint

The third viewpoint of the thesis research was methodological. The related aims were described as analyse, assess, and adjust a selected set of UCD methods for research and development of clinical ICT systems. This objective was derived from the findings in the literature review that usability research has focused on a usability evaluation approach at the expense of reviewing the applicability of UCD methods (particularly field study methods) in clinical ICT system research. Accordingly, as the objective of this research was to adjust the approach to clinical technology to incorporate more UCD methods, understanding the challenges and possibilities of involving users in development work was also paramount. No research had been previously conducted on clinicians' experiences with IT development, or their preferred ways of participating and contributing to this development.

The sixth research question was as follows:

Q6) Are the clinicians interested in contributing to the development of their clinical IT systems? What kind of experiences do clinicians have with respect to current development activities?

Physicians seem to be highly motivated and interested in contributing to the development of their currently used IT systems (chapter 6.8). The respondents preferred direct feedback, connection to discussions with developers, and an opportunity to develop IT systems in close collaboration with developers as the best methods of collaboration (chapter 6.8). According to study results, no fewer than every second physician (of the 3,741 physicians who responded in the questionnaire study to the question addressing the physicians' interests in participating in IT development activities, Paper V) was interested in discussing her experiences if the organization had a physician responsible for collaborative actions with the software provider. More than one physician in three stated an interest in introducing their work to software developers if the latter would come to the workplaces. Only 649 (17.3%) of the respondents were not interested in taking part in development activities. This is a significant finding that encourages the application of user-centred development activities.

Physicians' experiences with the current practices and methods of participation in IT development are quite negative. In general, the questionnaire study results showed strong dissatisfaction with the physicians' abilities to have an impact on the development of their current systems. Furthermore, a significant number of physicians were disappointed with the ability of IT system providers to produce corrections and changes rapidly and in the desired manner.

These study results supported the earlier findings indicating a lack of user-centred healthcare IT systems development. One of the challenges in practice for UCD is that development activities should be integrated together with the physicians' daily work in

healthcare organisations. The empirical findings indicate that, currently, direct communication between developers and clinicians is lacking. From the methodological viewpoint, factors to be considered include innovativeness of collaboration practices; resources; and attitudes of healthcare organisation representatives, managers, and developers. Furthermore, the results indicate the need for improved methods and practices for ICT development and for enhanced communication between developers and end-users.

The seventh research question dealt with methodology experiences from three empirical studies:

Q7) Based on empirical studies, what are the perceived advantages and challenges in using the UCD methods in the research of clinical ICT system use?

The reported experiences with the selected UCD methods (chapter 7.3) can be seen as to address the established need for improved user-centred development methods in the health informatics field. The experiences were gathered during the empirical studies, and they are based on the author's subjective observations as well as reflections on discussions with other research group members (as indicated in papers I, II and IV, all three studies were conducted in collaboration with numerous other researchers). The perceived advantages and challenges of the three UCD methods applied (contextual inquiry, interaction sequence illustration analysis, and a tailored usability questionnaire) were evaluated in relation to achieved study results and the author's earlier experiences with UCD methods in other research domains.

Compared with typical usability evaluation methods, **contextual inquiry** in particular may provide valuable support for user-centred development activities. In the empirical studies, the method was found suitable for increasing the understanding of clinical practices, contexts of work, and end-users' interaction with IT systems among researchers and developers. Additionally, inquiries conducted in real clinical contexts provide rich qualitative data for the purposes of developing new concepts and visions of future ICT systems. Similar findings have already been reported in other domains; however, the contextual inquiry method has not been applied widely in research of clinical ICT systems.

In the dictation and nursing documentation studies, the applied methodology approach was a combination of inquiry-guided field study and inspection-based evaluation. Inspections via interaction sequence illustration analysis and expert review enabled the researchers to gather concrete and detailed information about the steps and stages of interaction, usability of user interfaces, and effectiveness of use. Particularly, the experimental use of the **interaction sequence illustration** analysis method provided promising findings; however, more research needs to be conducted to better understand the advantages and challenges of the method. Experiences suggested that a remote analysis enables thorough walkthroughs that can be conducted not only by usability specialists and by developers but also by the users of the system. The possibility for remote analysis is especially important in the healthcare domain because conducting on-site analyses may be difficult due to sensitive topics being discussed between the physicians and the patients.

The **tailored usability questionnaire** for physicians' clinical work can be seen to present a methodological contribution to the fields of health informatics and usability research. The design of the questionnaire items draws from a conceptualisation of usability of clinical ICT systems and included three usability dimensions (described in Paper IV). In addition, the questionnaire incorporated several usability and use-related themes. Compared to established usability questionnaires, a tailor-made questionnaire has several advantages. Questionnaire studies typically address usability at an abstract, not context-

sensitive level. When designing a questionnaire and addressing usability as a generic, non-contextual property, the following challenges may arise: we assume that respondents are able to determine what the concepts of "ease of use" or "easy location of information" cover. However, the development of such a questionnaire required understanding of usability issues and of the particular context of research – of the characteristics of clinicians' work and working environments, as well as the variety of organisational settings.

The quantitative research approach, however, has a low descriptive value from the viewpoint of UCD. For example, general hints regarding problem areas may be provided by a usability questionnaire. On the other hand, such a questionnaire will often be unable to detect concrete weaknesses in a system or reveal the causes of these weaknesses. Therefore, supplementary data gathering using field studies is needed to create a deeper understanding of contextual needs and current problems, and address concrete development and redesign activities.

The *methodological triangulation* approach is encouraged by several findings; for example, it has been described that multi-method evaluation may increase the completeness of the study (Ammenwerth et al, 2003), and that no single usability evaluation method is effective in all circumstances (Jaspers, 2009; Horsky et al., 2010). Given this, it can be argued that the field study approach for clinical ICT development is highly applicable and relevant. The relevance is also emphasised in the following comment by Svanæs et al. (2010):

> *To be able to research usability issues that go beyond what can be found by a traditional stationary user interface evaluation, it is necessary to conduct usability studies of mobile electronic patient record systems in physical environments that simulate the conditions of the work situation at a high level of realism.*

Q8) What are the characteristics of clinical contexts that need to be taken into account when applying UCD methods?

Experiences from the empirical studies suggested the following main reasons for conducting research in real clinical contexts. First, the arrangements provide the researchers an opportunity to familiarise themselves with the characteristics and diversity of the clinicians' working environments. Second, the observations of the real-life use of clinical ICT systems reveal needs that users are unable to articulate. Particularly, inquiries made it possible to apply a task-oriented approach to the analysis of the actions of clinicians with documentation and other interactive systems, and thereby, obtain concrete and detailed information on system use and related clinical work situations, including aspects of information-sharing and communication. Third, access to real clinical environments is essential to create a comprehensive understanding of the user context and to gather reliable and rich data.

On the other hand, UCD methods need to be adjusted to clinical contexts and contextual aspects when performing research in real-life clinical surroundings. These aspects include the following:

- privacy and data security issues
- a high degree of communication and collaboration among professionals
- diverse and dynamic working practices
- a variety of organisational environments
- the hectic nature of clinical work
- the wide range of IT systems in use.

These aspects indicate challenges for research and system development – the aspects describe the context in which field studies are conducted and for which systems they are developed and designed.

Issues of **privacy and data security** indicate the challenges researchers face in gaining access to clinical environments and records, and in utilising the recorded data. Accessing clinical environments requires negotiations with organisation representatives. Without exception, clinical work includes patient care and data-management activities. Caring giving situations involving real patients and their personal health and well-being are very sensitive by nature, as are the data collected. Observations or inquiries in such situations require careful planning. The recording of real patient data, even when patients are not present (e.g., during times when physicians are conducting dictations) can only occur after making special arrangements between researchers and healthcare organisation representatives. All recorded data must be anonymised no later than the analysis phase, and modified as needed. If the research is conducted in an educational or a simulated setting, the researchers must be aware of the related constraints and restrictions, and of how these reflect in the study findings and interpretations.

Communication and collaboration among professionals, as well as considerations of **diverse and dynamic working practices**, bring forth challenges for researching usability in clinical contexts. Based on literature review (chapter 3), these aspects of interactive systems use are not often included in usability studies and thereby require special attention. Studies with UCD methods typically involve a rather small number of users and focus on examining the predetermined situations or the use of the particular interactive systems. **The variety of organisational environments** and sheer number of end-user groups are two problematic factors when one attempts to identify the main user groups, select representative users for the studies, and involve these users in intensive data-gathering sessions. For example, the large-scale EHR systems are used in hospitals and healthcare centres, including in numerous areas of medical specialty. The type of end-user and organisational environment will influence every individual user's experience with the EHR system.

Another challenge for conducting studies in clinical environments relates to the **hectic nature of clinical work.** While working, clinicians tend to be extremely busy, and the work often includes unexpected interruptions and emergency situations. Therefore, clinicians have limited opportunities for dedicating time to research and development activities while on duty.

The characteristics of clinical work also bring forth challenges with respect to planning studies and IT redesign activities. When planning the studies, the scope of research in the clinical context might be difficult to determine: Which are the aspects of current work procedures and technologies that need to be redesigned and developed? The researchers need to have a sufficient understanding of the **variety of ICT applications in use** as well as of related working procedures and practices. New ICT applications typically require changes in working procedures. These procedures need to be designed side-by-side with the technology. On the other hand, the technology environment should be seen as a whole. New applications should be flexible and adapt to various use contexts and purposes. If the work aims at developing new applications or improving the existing ones, such knowledge is even more crucial. The work often requires a multidisciplinary approach and multiple stakeholders, including the usability practitioners and researchers. In the absence of this participation, developers seldom have sufficient knowledge of medical or nursing work and terminology, the area of medical speciality of the unit, or working procedures and organisational practices. On the other hand, researchers are not typically familiar with healthcare-related governmental or professional regulations, or the technical and architectural aspects of information systems.

The described challenges indicate that it is important for the researchers and software developers to take into account these characteristics of clinical contexts when studying and designing healthcare ICT systems. The research and development work should aim at focusing on those practices and ICT tools that are most important from the perspective of clinical work. What kind of criteria of methods should be applied to identify and to select these ICT tools? With respect to this question, *the triangulation* of UCD methods with the quantitative research approach may provide a means for determining the criteria and also anticipating the impacts of redesign and development activities. However, conducting research to determine and plan efficient and effective UCD activities in healthcare and other domains remains a methodological challenge for HCI and related research fields.

9 DISCUSSION

This chapter discusses the conclusions, considers the challenges facing healthcare ICT development today, discusses the relevance as well as strengths and weaknesses of the research, and suggests topics for future work.

9.1 On the Conclusions of the Research

Currently, clinical ICT systems and their development seem to be in a worrisome shape, at least in Finland. The empirical study findings and the first conclusion show what the situation is like when the user-centred approach to technology development is lacking. The thesis provides evidence for both detailed (problems which are related to user interface characteristics) and more comprehensive (problems which are related to interaction design and e.g. lack of a needed functionality) usability problems. The study findings (particularly those reported in papers I, IV and VI) demonstrated that there are mundane details that make some clinical IT systems inferior to others. These details may appear minuscule compared to the scale of visions that typically motivate the development and introduction of new healthcare IT.

Furthermore, the following two comments illustrate the current situation as experienced by physicians. (The comments have been translated from Finnish by the author, and they represent a selected set of open-ended answers given to a national questionnaire study (Paper IV) on the question concerning general feedback about the study and questionnaire topics.)

> *"Many complain about the costs of healthcare delivery. Nevertheless, we waste money on diverse IT systems, which are considered poor and non-inoperable. In our organization, the implementation of a new IT system decreased the efficiency about 10 percent, and we could also afford this. We do have a wealthy society, since we can waste resources, capital and professionals' time on duty by using poorly working systems like this. There is no direct communication channel between our unit and the software provider. Apparently none of the Finnish vendors are interested in user-oriented IT development. Maybe we should hire a software company which is specialized in developing video games to develop new systems for healthcare use. Those games tend to be much more advantageous than our systems."*

> *"I really appreciate the study. Hopefully it will finally have some effect on development work. From the physicians' viewpoint, the only tasks that IT systems are able to support are being able to look at radiology pictures on the computer and have access to the patient's medical history without the need for searching paper-based files. Otherwise, IT systems and related development work have made the physician's daily work more and more cumbersome and time-consuming. My estimate is that in the clinic an appointment with the patient takes about 30 minutes: I spent about 5 minutes with the patient and for the other 25 minutes clicking and socialising with the computer. After every improvement, the use of the EHR system requires more and more time. Instead of treating the patients, the physicians' principle duty today seems to be the maintenance of the computer and production of statistical information. EHR system X is particularly non-user-friendly. There are no settings that a user can modify. Each and every single and simple operation requires tens of clicks, and similar kinds of selections need to be done again and again when dealing with numerous patients.*

These comments together with the empirical study results indicate that at present lot resources are wasted due to work dedicated on IT use and inefficient documentation.

While the empirical studies yielded primarily negative results, the positive results should not be neglected. One example of successful design and implementation of healthcare technology is the use of the voice-recognition dictation technique in radiology units. Also, the nursing documentation study revealed some positive findings. Nurses seem to prefer electronic documentation and are not willing to return to paper-based documentation. The main reason for this was the accessibility of information (compared to papers electronic documentation is easily accessible) and the reuse of documentation (e.g. when a care plan is accurately written, it can be utilized afterwards in care process and documentation). However, these findings raise some questions. What level of accessibility or user-friendliness should the technology benefits of healthcare IT systems be compared with? What is the expected and sufficient level of usability? What is the point of comparing the achieved benefits to what was achievable with paper-based practices? Shouldn't we compare healthcare to other industrial domains in which ICT applications are widely used and adapted, or to those applications and devices that are widely used by consumers in industrial countries (e.g. smartphones, laptops and iPads)? With respect to these, it seems the currently used EHR systems in Finland are completely antiquated.

The degree to which traditional usability evaluation studies have flourished in the health informatics field over the past years has been somewhat surprising. In the HCI field, the academic focus has long been on other topics, e.g. on the field study approach and rapid prototyping methods. In the industry, the evaluation methods, especially usability testing and formal heuristic evaluation, were during the 1990s considered very important based on their actual impact on product development (Gunther et al. 2001; Vredenburg et al. 2002). According to the same studies, UCD methods were within industry generally thought to have improved product usefulness and usability, although the degree of adoption of user-centred methods was quite uneven across different organisations.

The fourth important activity of user-centred design is requirements specification. The iterative development process for interactive systems, described by ISO 13407 (1999) and later on redefined by the ISO 9241-210 standard (2010), consists of four UCD activities: 1) specify the context of use, 2) specify user requirements, 3) produce design solutions, and 4) evaluate the design. The literature review (chapter 3) showed that usability-related studies in the health informatics field and around clinical system development have particularly focused on evaluation activities, and some on design activities. A few researchers have reported user research studies, which have been conducted in the early phases of the system development cycle. Surprisingly, however, articles reporting user and usability requirements elicitation and specification are extremely hard to find. Recently published articles by Jokela (2010) and Lehtonen et al. (2010) seem to be the few focusing on this important phase of the interactive system design process. Both these studies explored usability requirements in call-for-tenders of software systems, including healthcare IT systems. Jokela (2010) studied different options for determining usability requirements for a critical healthcare system. The study showed that determining appropriate usability measurements and setting target levels is a challenging task, requiring remarkable resources and usability expertise. The study by Lehtonen et al. (2010) analyzed to what extent public authorities require usability. They found that the authorities seem to have some concern about usability; however, the usability requirements mentioned in call-for-tenders were found invalid and /or not verifiable. All these findings on the lack of usability and user requirements considerations emphasise the need for conducting more research around these important topics in the health informatics field.

In the HCI field, recent discussions on usability have pointed out that the scope of the usability approach should be broadened. Traditionally, usability is associated with human-computer interaction, whereas user experience has emerged as a new concept that emphasises the emotional aspects resulting from the use of a system (this viewpoint has been pointed out in 9241-210 standard). The widely cited definitions consider the aspects of user experience; however, the common misconception is that usability refers solely to making products easy to use (ISO 9241-210, 2010). For this reason the recently launched ISO 9241-210 standard (2010) argues that usability should be understood as a broad concept that includes perceptual and emotional aspects typically associated with user experience. Furthermore, Hertzum (2010) describes six images of usability (universal, situational, perceived, hedonic, organisational and cultural) and states that usability studies often focus on the individual user's operation of a system and bypass for example considerations of collaboration.

In this thesis, the broad interpretation of usability made it possible to increase the understanding of contextual characteristics and also address issues that are not typically acknowledged in usability related studies in the health informatics field. Several researchers have described characteristics that differentiate the healthcare domain from other research fields. These include a high degree of communication and collaboration among professionals (Bardram et al., 2006; Lenz et al., 2002), diverse and dynamic working practices (PAHO, 1999; Davis, 1973), and governmental and professional regulations (Nemeth et al., 2005). Furthermore, Bardram et al. (2006) have described the characteristics of healthcare work that need to be understood when developing ICT applications: nomadic work, collaboration and coordination, mobility among heterogeneous devices, rapid context switching, and integration of digital and physical work. Compared to these, the characteristics pointed out in this thesis are highly similar.

These characteristics need to be carefully considered when planning UCD studies and applying UCD methods in clinical ICT system development. The empirical studies indicated that UCD methods can be used to support and inform the design of new healthcare ICT systems. There are several reasons for involving UCD specialists in development work. First, the end-users' abilities to envision new solutions is limited; this finding was clear from the questionnaire study with physicians, in which the physicians were asked to describe their visions on future EHR systems. In the digital dictation study, the use of scenario-based approaches supported discussions about future, and providing users with a means to express hopes and desires based on their experiences. Second, developers seldom have sufficient domain-specific knowledge or understanding of field study methods or processes of UCD. Nevertheless, it should be noted that the work requires experienced UCD specialists who have sufficient understanding of clinical work and related contexts. Depending on their working history and areas of domain specific knowledge, the UCD specialists may not have previous experience on healthcare ICT development or domain specific characteristics; however, they know what kind of user data should be gathered and how to increase the understanding of contextual issues and to support the user-centred development work.

9.2 Playground of Healthcare ICT Development

The following scenario describes a real-life situation from an end-user perspective: the impact of EHR system implementation in a healthcare clinic observed by a physician. The scenario illustrates how the failures in system design (particularly relating to intuitiveness of use and learnability) and insufficient understanding of clinical ICT systems as integrated parts of clinical technology environment may appear in practice, leading to significant economic loss and unwanted non-economic impacts.

> *I work as a physician in a clinic that is currently implementing a new EHR system. I'm suspicious of the new system, because I've heard that it does not have all the functionalities the current system has. All the physicians in our clinic are obligated to take part in 15 hours of training. In addition, we need to extend the appointments from 20 to 30 minutes. This is due to delays the new system is expected to cause at least during the first month. Patient records need to be transferred separately. The situation may involve decreases in quality of care and poses a serious threat for patient safety. This is unless the physician is able to recall all the necessary patient information... By now, a single computer in a clinic holds the old patient information. According to law the situation is acceptable; however, there is a doubt about the quality of care.*

Based on the scenario, the costs of low usability during the introduction of the new EHR system can be calculated as follows (using realistic estimates):

- Patients per day: before the change: 21, after: 14; this means a decrease of 33% during the first month in normal working days. The total decrease of patients/physician in a month is 175 (out of 441; -40%) (calculated with 21 working days in a month out of which 2 are spent in the obligatory system training).
- The clinic has 60 physicians. The total decrease of patients in the clinic during the EHR introductory month is 10,500.
- The average billing from a single appointment is €75.
- The total economic loss from the introduction of the new system is €787,500.

Furthermore, the scenario indicates that all existing data need to be entered manually into the new system. That generates additional costs. The change of the system may affect the quality of patient care, as not all data related to patient history are available for the physicians during the appointments. The change is also expected to have several non-economic impacts, such as weakening of the image of the clinic as well as frustration on the part of healthcare workers and patients.

With the scenario, the related estimates, and the presented empirical study results in mind, it can be argued that failures in system design and implementation have significant effects on efficiency of work, user satisfaction, and quality of care. The findings also raise several concerns about the tools clinicians use daily and the waste of operational resources due to failure in ICT development and user-centred design. Among other findings, the described real-life scenario pointed out clearly how the implementation work seems to be biased from the end-users' viewpoint: the expected benefits of ICT usage in clinical work are not achieved.

As described in the introductory part of this thesis, considerable amounts of money are continuously invested on healthcare IT. The thesis research questions the rationality of the investments, motives behind, and methods of estimating potential benefits as well as criteria for decision making. It would be rational to assume that the main drivers behind technology adoption in healthcare are, as described by Beaver (2003), improved quality and efficiency of care. However, the currently used clinical IT systems do not seem to

serve the needs of physicians or nurses, but instead make the daily work with patients more difficult and time-consuming. Still, healthcare organizations seem to share the endeavour of implementing the systems. Is it enough that the systems fulfil the managers' and administration's needs? And are these parties actually the primary users of the current healthcare information systems? The situation truly sounds confusing, and somehow it has turned upside-down compared to what is should be.

Another viewpoint on mismatch between information systems and the end-users relates to development work and practices. Today in software industry, it is crucial to ensure resources are being used as efficiently as possible, so tools to help select the most cost-effective methodology and the ability to prioritise design problems to be fixed by developers has become important. The empirical study on physicians' experiences with participation in system development pointed out the need for new innovative practices and arrangements for involving motivated users in development. Furthermore, a review by Shah and Robinson (2007) has indicated the key impediments when attempting to involve users: namely, lack of resources, communication, and cooperation between users and developers, attitudes of technical developers, and lack of understanding and appropriate knowledge about methods to be used. Jaded and Delamonte (2008) and Hersh and Wright (2008) have recently expressed their concern about the lack of expertise and specialised workforce dealing with healthcare information technology development.

These findings argue on behalf of a sufficient level of expertise and cooperative development of user-centred clinical ICT systems. In short, the message to the developers of clinical ICT systems is:

- The developers need to achieve a better understanding of the healthcare context and tasks in order to develop appropriate tools for patient care. Clinicians should be able to focus on their primary tasks – caring work. So far, the adoption of healthcare ICT has created a lot of additional work that is not related to clinicians' primary tasks.
- The technology environment in healthcare should be understood as a whole, and the software systems and work activities should be developed simultaneously.
- User participation during various phases of development work is crucial. ICT systems should fit into clinicians' working procedures in various healthcare contexts.
- Developing healthcare ICT systems with high usability requires designers who are specialists in interaction design and user-centred system development. Although user participation during various phases of development work is crucial, it must be remembered that users should not be considered as representing or replacing interaction designers. Instead, physicians are experts in medical practice and clinical work, and they may be able to determine the kind of problems they have with the currently used systems. Therefore, end-users are the primary source of use-related information, but they are not designers.

In addition to developers, healthcare organisation representatives arguably have an important role in clinical ICT development, since they are in charge of the investments and have the power to determine the criteria. An interesting question is, do customers (healthcare organizations) require usability, and if they do, are they able to determine valid and verifiable enough usability requirements or criteria for the systems? In this sense, it is easy to blame the organizations for accepting poor usability – if the customer does not require usability and is not willing to invest in it, it is not in the software providers' interest to develop or offer something else than is required. It seems that healthcare organisations have realised some practical problems with their current clinical IT systems and are willing to invest huge amounts in system redesign (e.g. HUS Administration, 2009). The redesign work requires expertise in the areas of usability and

user-centred design, as well as understanding of clinical work, technical constraints, and the capabilities of ICT. On the other hand, healthcare organisations are often seen to have few alternatives when making decisions on IT investments. This is due to the fact that the Finnish markets are unattractive to international vendors, and the largest vendors share the bulk of the market in all healthcare sectors.

What kind of role should the government have in guiding the further development of healthcare ICT systems? In Finland, recent discussions concerning the creation of a national health archive, and on deployment of a single health record system, have raised the question of how development work should be supported and guided at the national level. The procurement of healthcare technology systems is regulated by laws and rules that do not sufficiently promote participation and communication between end-users and developers. Since development work is often characterised as being iterative and ICT systems are widely deployed, procurement specifications should require vendors to state how they will organise end-user participation in the further development of their products.

The third viewpoint on the role of government relates to the possibility of small companies entering the market to help develop innovative clinical ICT solutions currently not available in the Finnish marketplace. At present, the dominant vendors are not interested in providing open interfaces. The situation raises challenges for developing, adopting, and integrating new solutions (e.g. iPad and smartphone solutions) with the currently used large clinical IT systems. From this perspective, it seems that the monopoly situation and dominating vendors have the ability to hinder the progress of healthcare technology development and adoption. Therefore the question is: Who should guide the work and determine the rules?

9.3 Relevance of the Research

In the HCI field, more and more research has been devoted to the concept of *user experience.* According to recent discussion and publications, user experience can be considered as the 'sibling of usability', although the relationship (and the distinction) between these concepts is not completely clear. The ISO 9241-210 standard makes user experience a more versatile concept that is applicable for comprehensive analyses regarding user viewpoints during development. In relation to these discussions and to the evolving field of user experience research, it is easy to argue that the focus of the presented research – study of the use and usability of clinical ICT systems, with an emphasis on user- and task-centred perspectives in contrast to system-centric and testing-driven assessment – can be argued in favour of, and is clearly relevant.

The described empirical studies and the related results are unique in several ways. Currently, relatively little can be found in health informatics literature regarding domain-specific contextualisation of usability or end-users' experiences with the usability of numerous ICT systems in clinical settings. The aforementioned three perspectives on clinical ICT usability are to inform researchers about context specific aspects of usability. Previously no such perspectives (usability criteria or dimensions) had been introduced in the fields of health informatics or usability research. Furthermore, the findings on the current state of clinical ICT systems usability have novelty value, since the applied research approach was not typical for health informatics studies. In particular, the tailored usability questionnaire study with nearly 4,000 respondents can be considered exceptional compared to usability studies in the field. Findings from dictation and nursing documentation system studies, in which field study methods were applied, complemented the questionnaire results and thereby made it possible to mitigate limitations of the questionnaire technique and the quantitative approach.

The relatively small number of usability studies may derive from the identified challenges in applying the UCD methods in the health informatics domain. Some of these challenges are illustrated in the following paragraph, written by Peute et al. (2008) in their literature review article 'Usability studies on interactive health information systems: Where do we stand?'

> *Integration of usability in the development processes of healthcare information systems is challenging. Insights into where usability has effectively been integrated in design and evaluation may lead to the development of new metrics on which to evaluate healthcare user interfaces. Future analysis of studies of the systematic review will focus among other things on the applied strategies of usability methods on different types of healthcare information systems and the experiences and lessons learned of combined methodologies in usability evaluation studies. (Peute et al., 2008)*

With this citation in mind, the thesis research deals with relevant and timely topics. First, the research area has high relevance in practice. The need to consider user perspectives in healthcare technology development has been established both in academic research forums and in public discussions. At present, a lot seems to be going on around clinical IT systems research. For example, researchers are planning cross-country studies for the monitoring of national health information system implementations (Hyppönen et al., 2011b). In Sweden, a national questionnaire study on healthcare IT use was recently conducted to obtain an overview of the current situation and of technology usage from the viewpoint of end-users (UserAward, 2011).

Second, academic research in the health informatics field seems to be lacking commonly established models, theoretical approaches, and practical procedures for user-oriented

clinical ICT system development and research. For example, several essential concepts such as *usability of healthcare information systems* and *contexts of healthcare ICT use* have not been described or conceptualised. In general, it seems that *usability* is a widely used, but narrowly understood concept. Additionally, the concept *user-centred design* (UCD) appears in very few research papers. Usability-related research in the healthcare IT field focuses on evaluation activities and assessment. Alongside with usability evaluation, other methods, particularly field study methods, should be more widely used to support UCD activities during the design and development phases. This argument is supported by recently published articles, which have suggested the adoption of usability testing techniques to gather user requirements (Bellwood et al., 2011) and the use of qualitative methods across the software development lifecycle in health informatics (Byrocki et al., 2011). Further, in their recent article Kushniruk and Turner (2011) have re-examined the term *user* in the context of socio-technical approaches to healthcare IT development and emphasised the need to differentiate between types of users and changing expectations of their roles in development projects across design, implementation and evaluation. The author believes that the work described in this thesis provides guidance for analysing and structuring the research area thematically and methodologically, and thereby promoting the adoption of UCD approaches to support the development of clinical ICT systems. In the future, the user-centred approach is expected to have an even more essential role when the idea of patient-centred healthcare (Davis et al., 2004; Haux et al., 2002) and related intensive collaboration between clinicians, patients and other involved parties will take place in practice.

Finally, the multidisciplinary nature of the described research can be used to argue on behalf of relevance. The work shares interests with other closely related research fields, e.g. with ongoing studies on computer-supported cooperative work (CSCW), sociology of technology (Nardi, 1996; Hyppönen, 2007), and information systems success (DeLone and McLean, 2003; Hyppönen et al., 2011a). Within the CSCW field, researchers have for several years been attracted by the conception, construction, and use of CSCW technologies in healthcare, including examination of electronic health records in collaborative clinical settings (e.g. Berg, 1999), collaborative technologies in healthcare (e.g. Bardram, 2000; Bardram et al., 2006; Bardram, 2009) and the collaborative practices of patient care teams (e.g. Reddy et al., 2001; Xiao, 2005). Recent studies have focused on diverse issues concerning computer-supported collaboration and co-ordination in healthcare, for example on the design of applications to support digital clinical documentation (Tang and Carpendale, 2009; Cabitza et al., 2009), the investigation of multidisciplinary team meetings within healthcare settings (Robertson et al., 2010), and research related to information management in emergency medical service settings (Dovigo and Redaelli, 2010).

Research on user perspectives of technology use seems to carry considerable cross-disciplinary interest, although the used concepts and approaches are somewhat different. For example, the national questionnaire study with physicians indicated that several items in the questionnaire addressed both usability attributes and information system success variables (DeLone and McLean, 2003; Hyppönen et al., 2011a). The further conceptual analysis around concepts of *usability, context, user satisfaction, perceived usefulness, perceived ease of use*, and *user acceptance* should carefully consider the mutual interests of usability and health informatics research with other academic research fields, e.g. with information and communication theory, information system research (e.g. article by Davis (1989) discusses these concepts), and measurements of information systems success (DeLone and McLean, 2003).

9.4 Strengths and Weaknesses of the Research

The thesis research approached the study issues both qualitatively and quantitatively from practical, conceptual, and methodological viewpoints. In addition, the three empirical studies included a range of clinical ICT systems and clinicians from numerous healthcare units. The approach applied to the study of usability of clinical ICT systems argues on behalf of the validity of the research. The study results enabled the drawing of a general picture about the usability of the clinical IT environment, but also addressed user needs and problems at a concrete and detailed level from a highly qualitative and interpretive viewpoint.

On the other hand, the range of healthcare technologies in place today is huge. Therefore, the presented results should not be over-generalised. As expected, all the empirical studies addressed the use of EHR systems, since from the clinician's perspective these represent the primary source of patient data, and are pivotal for daily work. The critical findings particularly reflect current problems in the use of these systems in Finland. However, it is unclear how generalisable the results are to other countries in which healthcare technologies have been widely adopted.

There are some limitations and validity issues that need to be acknowledged and addressed. First, the described literature review (in chapter 3) was not conducted following a systematic literature review procedure. The literature review was conducted in a way that the author searched through several relevant research and publication forums and ended up including 93 publications from health informatics journals (e.g. Published in International Journal of Medical Informatics, Studies in Health Technology and Informatics, Methods of Information in Medicine, and Journal of Biomedical Informatics) and human-computer interaction related conferences and journals (e.g. International Journal of Human-Computer Studies, International Journal of Human-Computer Interaction, Journal of CSCW, ACM Transactions on Computer-Human Interaction, NordiCHI conference, CHI conference, and CSCW conference). This resembles a systematic literature review process, but it was not done by following the exact rules and guidelines of the systematic literature review method.

Second, the review aimed at covering a variety of perspectives on user-oriented research and study results. However, in total, a relatively small portion of all available publications were included in the analysis. These decisions were reached for reasons of expediency. Since there are no special forums for publications about user-oriented healthcare ICT development, the articles were searched from various forums, particularly journals and conferences related to health informatics and usability research. The selected articles illustrated a variety of qualitative and quantitative research approaches to healthcare ICT use and development, and hence the author did find the selected group representative enough for the purposes of the descriptive literature review.

Third, as pointed out earlier, the empirical studies were able to address the use of several clinical ICT systems, with particular emphasis on EHR systems in the work of physicians and nurses. The studies also focused on researching user needs, experiences, and expectations with regards to the currently used systems. However, there is a need to approach the earlier phases of development, namely the specification, design, and construction point of the systems. The gathered research data and reported results can be utilised in the design of new clinical systems for clinicians.

9.5 Implications for Design and Research

The current situation reflects those problems and challenges that occur when end-users' perspectives on technology use and development are not appropriately addressed and acknowledged. Implementation of IT systems generates not only predictable benefits but also unexpected consequences. The end-users' viewpoint on technology use should be the guiding principle when planning clinical ICT investments and determining the criteria for development and evaluation. The primary challenges in ICT development and investments seem to derive from the following. Often the managers who are responsible for making the decisions are not the system end-users themselves, nor are the software engineers who develop and design the systems. On rare occasions, typically after some hazardous consequences have occurred, developers may end up asking the end-users what they want and how the current systems should be improved. From the perspective of user-centred design, this is not the suggested way of designing and developing systems. Users are not designers. Instead, the interaction designers and UCD people are. And they have numerous methods for anticipating and researching the benefits and the effects of technology implementation, as well as for supporting the user-centred development of clinical ICT systems. During development projects, it is not enough to turn the mind-set into such "user-friendly" or responsive mode when difficulties or shortcomings occur. Instead, user-centred activities should be integrated into the development lifecycle from the very beginning and throughout the process.

Serious challenges seem to be related to turning the current situation of clinical ICT implementation and development upside-down – to a user-centred mode. Researchers have possibilities to contribute to the work. However, major challenges are related to the attitudes of other parties and the lack of leadership in change management. The contribution of this thesis is as follows.

Implications for research:

- Empirical exposition of existing usability problems and clinical IT system characteristics that make the systems inferior to others and hinder the efficiency of clinical work by physicians and nurses. (Papers I, II, IV and VI)
- Empirical exposition on the lack of opportunities for end-user (particularly physicians) feedback and participation in healthcare IT projects and system development in spite of end-users' self-reported interest in participating more actively. (Paper V)
- State-of-the-art review of usability-related research in the health informatics field based on a compilation of research articles published in health informatics and human-computer interaction (HCI) journals and conferences. (Chapter 3)

Implications for design:

- Identification of the main usability and interaction design problems based on an empirical analysis of the current state of clinical IT system usability in Finland. (Papers I, II, IV, V, VI, and chapter 6)
- Suggestions for improvements in currently used clinical IT systems and new ICT applications based on empirical studies. (Chapter 7.1)

Furthermore, the thesis reports the following scientific findings, which are based on empirical studies, and thereby makes headways towards additional contributions:

- Descriptions of the concept of usability of clinical ICT systems. (Papers I, II, IV, and chapter 7.2)
- Identification of advantages and challenges in the employment of a selected set of UCD methods in clinical contexts, and description of the characteristics of clinical contexts that need to be taken into account when applying UCD methods. (Papers III, IV, V, VI, and chapter 7.3)

Due to the multidisciplinary nature of the thesis, the contribution of the thesis is in the realm of interest for numerous groups involved in healthcare ICT development: health informatics communities, researchers in the fields of human-computer interaction and usability research, developers and vendors of healthcare technology applications, healthcare organizations, and parties responsible for guidance on development work at the national level.

9.6 Future Work

This thesis explored the use and usability of clinical IT systems from the viewpoints of end-users. The findings indicated that a significant amount of development work needs to take place to achieve the potential benefits healthcare technology applications offer, since the present systems do not meet their goals in terms of support of clinical work.

Future work should focus on design and development activities around clinical ICT systems. The suggested topics for future research include the following:

- Design reference user interfaces for nursing documentation and for EHR systems to support the development of currently used systems.
- Collaborative redesign of clinical IT applications with clinicians and developers, with specific emphasis on user interface and interaction design (e.g. digital dictation): a) study how UCD methods could be integrated into development processes to promote collaboration and communication between developers and end-users, and b) study the practices of user-oriented development from the perspective of developers and other stakeholders: describe the current practices, and identify advantages and challenges for the user-centred design approach. Based on the experiences from a) and b), create new practices to support collaboration and communication between developers and end-users, and apply and validate those in practice.
- Promote the use of the UCD approach in healthcare ICT research.
- Investigate what the prerequisites and challenges are for conducting successful pilot implementations of healthcare IT systems.
- Conduct research to understand the shared interests between usability research and other related research fields (e.g. information system success, sociology of technology, participatory design) in order to take full advantage of user-oriented studies and support user involvement in healthcare technology development work.
- Extend the research and development focus to involve patients as clinical ICT system users.

With regards to these topics, it is important to understand that usability is extremely context-sensitive by nature. The suggested activities share the aim of overcoming the current mismatch between IT systems and clinical work. The research and the contributions presented in this thesis can be considered as a step towards this aim.

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Papers

Paper I: Viitanen, J. (2009) Redesigning Digital Dictation for Physicians: A User-Centred Approach. Health Informatics Journal 15 (3), pp. 179-190.

Paper II: Viitanen, J., Kuusisto, A., Nykänen, P. (2011) Usability of Electronic Nursing Record Systems: Definition and Results from an Evaluation Study in Finland. In Borycki E.M., Bartle-Clar J.A., Househ M.S., Kuziemsky C.E., Schraa E.G. (eds.), International Perspectives in Health Informatics. Studies in Health Technology and Informatics 164, pp. 333-338.

Paper III: Viitanen, J. (2011) Contextual Inquiry Method for User-Centred Clinical IT System Design. In Moen A. et al. (eds.), "User Centred Networked Health Care", Studies in Health Technology and Informatics 169, pp. 965-969.

Paper IV: Viitanen, J., Hyppönen, H., Lääveri, T., Vänskä, J., Reponen, J., Winblad, I. (2011) National Questionnaire Study on Clinical ICT Systems Proofs: Physicians Suffer from Poor Usability. International Journal of Medical Informatics 80(10), pp. 708-725.

Paper V: Martikainen, S., Viitanen, J., Korpela, M., Lääveri T. (2011) Physicians' Experiences of Participation in Healthcare IT Development: Willing but not Able. International Journal of Medical Informatics (in press, doi: http://dx.doi.org/10.1016/j.ijmedinf.2011.08.014).

Paper VI: Viitanen, J., Nieminen, M. (2011) Usability Evaluation of Digital Dictation Procedure – An Interaction Analysis Approach. Lecture Notes in Computer Science 7058, Springer (2011) (in press).

Healthcare information systems should support physicians and nurses in their daily work with patients. However, critics indicate the prevalence of negative experiences and use related problems. This thesis includes three studies on usability of currently used clinical information systems. The results show that the systems do not support the clinical tasks well. This is due to numerous usability problems, and lack of computer support for multi-professional and cross-organizational collaboration between clinicians. Major improvements are needed to achieve the potential benefits technology applications offer. In order to overcome the mismatch between information systems and clinical work, it is important to understand that usability is extremely context-sensitive by nature. User-centred approach should be integrated into system development process: end-users should be actively involved and user-centred design methods applied to analyse, design, and evaluate solutions for clinical use.

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