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National questionnaire study on clinical ICT systems proofs: Physicians suffer from poor usability

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ABSTRACT

Objective: In the health informatics field, usability studies typically focus on evaluating a single information system and involve a rather small group of end-users. However, little is known about the usability of clinical information and communication technology (ICT) environment in which healthcare professionals work daily. This paper aims at contributing to usability research and user-oriented development of healthcare technologies with three objectives: inform researchers and practitioners about the current state of usability of clinical ICT systems, increase the understanding of usability aspects specific for clinical context, and encourage a more holistic approach on studying usability issues in health informatics field.

Methods: A national web questionnaire study was conducted in Finland in spring 2010 with 3929 physicians actively working in patient care. For the purposes of the study, we described three dimensions of clinical ICT system usability that reflect the physicians' viewpoint on system usage: (1) compatibility between clinical ICT systems and physicians' tasks, (2) ICT support for information exchange, communication and collaboration in clinical work, and (3) interoperability and reliability. The dimensions derive from the definitions of usability and clinical context of use analysis, and 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 research data incorporated 32 statements with a five-point Likert-scale on physicians' experiences on usability of their currently used ICT systems and a summative question about school grade given to electronic health record (EHR) systems.

Results: Physicians' estimates of their EHR systems were very critical. With the rating scale from 4 or fail to 10 or excellent, the average of the grades varied from 6.1 to 8.4 dependent on the kind of facility the physician is working. Questionnaire results indicated several usability problems and deficiencies which considerably hindered the efficiency of clinical ICT use and physician's routine work. Systems lacked the appropriate features to support typical clinical tasks, such as decision making, prevention of medical errors, and review of a patient's treatment chart. The systems also required physicians to perform fixed sequences of steps and

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tasks, and poorly supported the documentation and retrieval of patient data. The findings on ICT support for collaboration showed mainly negative results, aside from collaboration between co-located physicians. In addition, the study results pointed out physicians suffering from system failures and a lack of integration between the systems. The described study and related results are unique in several ways. A national usability study with nearly 4000 respondents had not been conducted in other countries in which healthcare technologies are widely adopted. The questionnaire study provided a generalized picture about the usability problems, however, it should be noted that there were significant differences between legacy systems in use. Previously, researchers had not approached contextual aspects of usability the context of clinical work, where numerous systems are in use. The described usability dimensions and the presented study results can be considered as the first step towards conceptualizing ICT usability in the unique setting of clinical work.

1. Introduction

Today, hundreds of information and communication technology (ICT) systems are used in healthcare organisations to serve physicians and other professionals in their daily work with patients. These systems cover a broad range of applications, from widely used electronic health records (EHR) and computerised physician order entry (CPOE) systems, to modern speech recognition technologies and mobile applications. Among other industries, healthcare has already profited extensively by the development of ICT. Although the technology-related benefits are obvious in theory, it seems that they are not clearly associated in the operating situations nor appeared in healthcare professionals' daily work. Indeed, what is known about the usability of the healthcare technology environment – the jungle of electronic systems and applications in which physicians, nurses and other professionals work daily?

User-oriented research in the health informatics field has tended to focus on ICT adaptation and user satisfaction issues, rather than on usability. Since the early 2000s, however, there has been growing interest towards usability and human-centred design issues. Typically, researchers have applied traditional usability evaluation methods [1,2] and focussed on healthcare information systems, particularly on EHRs, and their use in clinical settings (e.g. [3–6]). Additionally, several articles have aimed at promoting the adaptation of the evaluation approach by describing instructions for usability activities in healthcare settings (e.g. [7–9]).

The motivation for usability studies derives from empirical study results as well as worrying statements about failures in technology development and adaptation (e.g. presented by professors Heeks [10] and Haux [11]). The results from recent studies suggest that currently used healthcare information systems suffer from a high number of usability flaws which considerably hinder the use of computer systems. The evidence is strong: an EHR system has been reported with 103 flaws related to the complexity of information, a poor relation to work activities, and lack of support for mobility [3]; a commercial EHR in a large paediatric hospital has been reported with 134 flaws related to consistency, user control, flexibility, efficiency, and natural dialogue [4]; a CPOE system has been reported with 33 flaws related to user interface and user interaction issues [5]; and a handheld prescription writing application has been reported with 73 flaws related to interface design [6].

Despite the increasing trend towards usability issues, relatively little systematic data has been gathered on the usability of the clinical technology environment. Generally speaking, the focus of usability research seems to be heavily affected by the traditional approach of human–computer interaction evaluation. As an illustration of this, several evaluation studies share the following characteristics in common: they focus on a single healthcare information system already in use, apply traditional usability evaluation methods (user testing or usability inspections), are conducted in a specified use context, and involve a rather small number of end-users (typically healthcare professionals within the same area of expertise). This observation also applies to those few reported usability questionnaire studies used to evaluate hospital information technology (IT) systems [12–14].

It is easy to argue that more research is needed to investigate usability of ICT systems and the impacts current systems have on clinical work. The ISO 9241-210 standard 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* [15]. When reflected on in the domain of health informatics, the following question can be raised to address the success of ICT development and adaptation: Do clinical ICT systems support professionals' operative work? Are professionals able to conduct their work in an efficient and satisfactory way using these systems? From the viewpoint of healthcare professionals, research on the usability of a single system is somehow contradictory when considering their daily work and surroundings. The technology environment in clinical work consists of tens of ICT systems, of which several are used simultaneously (e.g. the process of electronic prescribing using EHR and other ICT systems). With the end-users' perspective in mind, it is easy to argue that research should address the usability of ICT systems in clinical contexts from a broader viewpoint: consider applications as integrated parts of the technology environment and describe the objectives of usability considerations

with regards to user's tasks and goals while utilizing numerous ICT systems in their daily work.

It seems that no empirical research has addressed the usability of clinical ICT systems from such perspective. Further, in health informatics literature, the definition for usability presented by the ISO standard [15,16] is often referred to; however, no specific clarification or definition has been presented on the concept of the usability of healthcare ICT. For instance, the HIMMS 2009 report describes nine principles of EHR user interface design with references to the ISO standard [16], and emphasises efficiency, effectiveness, safety, user satisfaction and cognitive workload attributes [17]. Likewise, a consultative report by Schumacher et al. [18] 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. Additionally, in their paper on the contextual nature of usability, Svanæs et al. [19] illustrate the context of use in healthcare settings with help of three case descriptions and highlight the importance of taking into consideration the contextual nature of usability. Based on these findings, one can argue that the contextual nature and the applicability of the definition for the health informatics domain tend to be poorly understood and inadequately addressed by researchers and practitioners.

2. Aim of the research

Marc Berg [20], in his article about the healthcare information society in the year 2013, has stated that:

> "*We can make systems that help 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*."

Previous research in health informatics field has not provided a general picture of the success of clinical ICT system development, although the results from usability studies have indicated serious challenges and failures in system use and adoption. Therefore it is unclear if we are closer to the first or second scenario described by Berg.

The overall aim of this paper is to contribute to usability research and user-oriented development of healthcare technologies by (a) informing the researchers and practitioners about the current state of usability of clinical ICT systems, (b) increasing the understanding of usability aspects specific for clinical context, and (c) encouraging a more holistic approach on studying usability issues in health informatics field. This paper reports results from a study that applied a questionnaire method to explore Finnish physicians' experiences on the use of their current ICT systems. The study aimed at addressing the usability from a broad perspective and providing a generalized picture about the current state of usability. Thereby, a tailored usability questionnaire, which would address the issues of usability from two intersecting perspectives (a traditional approach – an evaluation of human–computer interaction and the characteristics of a user interface; and a contextual approach – issues deriving from the characteristics of physicians' work and elements of the clinical context) and have the potential to reach a wide range of respondents was selected to be the used research method. The questionnaire study incorporated several ICT use-related topics, of which this paper focusses on those questions reflecting usability issues. The work to be described builds on earlier studies on usability of healthcare technologies [e.g. 3–9]. It draws from human–computer interaction (HCI) research [21–23], and shares interests with ongoing studies on sociology of technology [24,25] as well as information systems success [26–28].

3. Background: usability and context of use in HCI research

Several definitions and conceptualizations for the concept usability have been presented in the human–computer interaction (HCI) research field. Most of these describe usability as having a contextual property meaning that usability should always be defined and measured in relation to specific settings. In this chapter, we introduce the concept of usability and outline approaches on analysing the elements of context.

3.1. *Introducing the concept of usability*

In the early 1980s, computer science moved from the realm of scientists and other experts programming their own systems to everyday people's offices. Untrained users found applications difficult to use. The focus of evaluation in product development shifted from product assurance testing to integrated product design and development [29]. The importance of usability and user interface design became apparent as more and more people came to rely on technical devices to carry out everyday tasks in their work and at home.

Since the late 1980s, several definitions for usability have been presented in HCI literature. In his definition, Shackel refers to "the capability" of being used by humans [30]. Usability has also been suggested as a subcategory of usefulness and system accessibility [23,31]. According to Bevan, the objective of usability is to achieve quality of use as it lies in the interaction of the user with the system [32]. Further, Nielsen has defined five key attributes (learnability, efficiency, memorability, errors, and satisfaction) with which usability is traditionally associated [23].

Probably the best known definition of usability, however, is the ISO standard [15,16]: *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*. In addition to others, this 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. A product, system or service is not itself usable or unusable, but it has attributes which will determine the usability for a particular user, task, and environment. Furthermore, the ISO 9241-210 standard describes human-centred activities and design principles for developing interactive systems. From a development perspective, usability work should aim at designing systems which help users in achieving their desired tasks and goals. Fig. 1 illustrates the

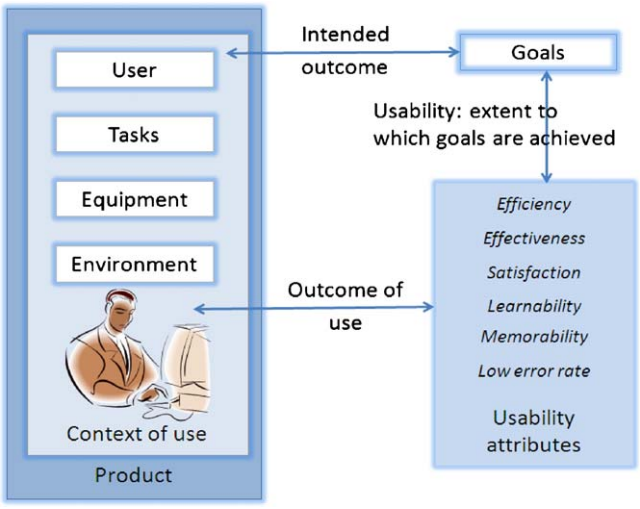

Fig. 1 – An illustration of contextual usability as described by the ISO standard and Nielsen [15,16,23].

components of usability and the relationship between them as described by ISO 9241 and Nielsen.

Traditionally, usability is associated with human–computer interaction, whereas user experience (UX) has emerged as a new concept which emphasises the emotional aspects resulting from the use of a system. Widely cited definitions for usability also consider the aspects of user experience; however, the common misconception is that usability refers solely to making products easy to use [15]. The recently presented definition for user experience, introduced by the ISO 9241-210 standard, clarifies more about the vague concept: *User experience refers to person's perceptions and responses resulting from the use and/or anticipated use of a system. User experience includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that occur before, during and after use* [15]. According to ISO standard, usability should be understood as a broad concept that includes the kind of perceptual and emotional aspects, such as job satisfaction and elimination of monotony, typically associated with user experience [15]. Following from this, the aim for designing for the whole user experience involves considerations of organisational impacts, user documentation, support and maintenance, training, and long-term use.

Seeing that the definitions for usability emphasise various viewpoints and cover issues ranging from emotional and temporal dimensions to user's goals, one can realise that usability is not only a characteristic of a user interface. Often, the objectives of evaluation studies are expressed as a list of adjectives, e.g. referring to the key attributes described by Nielsen [23]. Instead, usability should be understood as a multi-dimensional property, highly dependable of the context of use.

3.2. *Approaches to understanding and analysing context of use characteristics*

In the 1980s, usability work was largely about measuring and broadly comparing different interface components. "Ease of use" was the guiding objective for evaluation: the more successfully people could accomplish their objectives, the more usable the product was judged. Later on, in the 1990s, it became obvious that the research in the HCI field was no longer dealing solely with software systems or applications used in controlled environments like office workplaces. Among others, researchers Bannon and Bødker [33] argued that theoretical approaches, particularly cognitive science-based theories, are hindered by the following challenges: detailed task analysis and the idealized models created through task analysis may fail to capture the complexity and contingency of real-life action. From the point of view of complex work settings, the research may overemphasise the interaction between one user–one computer in contrast to the ever-ongoing cooperation and coordination of real work situations. These arguments were also supported by Mantovani [34] who emphasised the need for awareness of social dimensions beyond the task-artifact cycle. Therefore, it became essential to consider the richness of technology as well as the aspects of social, physical and temporal contexts of use both in usability research and system development.

To overcome the changes and challenges faced, approaches such as activity theory on information systems and computer supported collaborative work (CSCW), to mention but a few, were introduced to better understand and scope the contextual aspects around the design and development of interactive systems. Furthermore, several conceptualizations for the concept "context of use" have been presented by researchers working in these research fields. According to ISO standard [15,16], "the characteristics of the user, tasks and organisational, technical and physical environment define the context in which the system is used". These elements are also part of the definition by Dourish, who claims that context should be understood as an interactional phenomenon: context arises from the activity and is relevant to particular setting, instances of actions and parties to that action [35]. Alongside this, the conceptual model by Mantovani can be seen as complementary, since it accounts for cooperation and communication processes, and is built on three levels: social context (as the result of interaction between a set of cultural models), interpretation of situations (in which concepts "opportunities", "interests" and "goals" are used to describe the actor–environment interaction), and local interaction through artifacts (with considerations of local person–computer interactions for the performance of a particular task) [34].

Interestingly, all these conceptualizations (by ISO standard [16], Dourish [35], Mantovani [34]) concur with context being conceptual, not just physical phenomenon around interactive systems. Although these conceptualizations approach the phenomenon from various levels of abstraction, they suggest components of the same kind though which to describe the phenomenon "context". These are:

- *User* (or actor) meaning the parties involved in actions.
- *Systems* (or tools) the users interact with. Nevertheless, "equipment" is also used in the ISO standard [16], and "artifacts" and "computers" in Mantovani's conceptualizations [34].

- *Activities* (or tasks) – refer to interaction between the user and the system in various levels of abstraction, typically those actions required in achieving a goal.
- *Environment* (or setting, including physical, social and organisational issues). According to the ISO standard [16], the environment refers to the physical ambient, social and cultural environment, and attributes of the wider technical environment. To be more precise, the social and cultural environment addresses aspects of work practices, organisational structure, attitudes [16], and even collaboration and communication and cultural rules and models [34].

4. Perspectives on usability in clinical context – Background of the questionnaire design

In designing the questionnaire study for physicians we utilized the previously described theoretical background to gain an understanding of usability in clinical context. In the following chapters we illustrate the components of clinical context of use from the physicians' perspective and describe the aspects of clinical ICT system usability which were included in our questionnaire study.

4.1. *Illustrating the clinical context of use characteristics from the physicians' viewpoint*

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. These rather generic observations already point out some aspects of clinical work. To deepen the description, the four components of context (user, systems, activities, and environment, described in Section 3.2) can be used for illustrating the clinical context of use characteristics from the physicians' viewpoint.

User. Together with nurses, physicians are the primary users of the current healthcare ICT systems: electronic health record (EHR) systems, decision support systems, computerised provider order entry (CPOE) systems, and other applications. When thinking of physicians as end-users of these systems, they should not be considered as homogenous but heterogeneous, since in several aspects their needs, skills, interests towards the use of these systems, as well as responsibilities in clinical work vary. Further, physicians' backgrounds are diverse with regards to their work history and they have specialities in various areas of medicine (e.g. an emergency physician focuses on the immediate decision making and action necessary to prevent death or further disability, whereas a family physician is concerned with the total healthcare of the individual and the family).

Systems. From the beginning, healthcare information applications were developed to deliver relevant information to the healthcare professional and to support the healthcare process by enabling a seamless flow of information between various stakeholders and distant locations [36]. Today, the technical environment in healthcare organisations consists of thousands of healthcare information systems, medical devices, and other technology applications. Additionally, handheld technologies, as well as wireless and mobile applications, are entering the field. As an illustration, physicians use numerous information technology applications for a variety of purposes: receiving laboratory results and other clinical information online, online references such as clinical guidelines, electronic prescribing, computerised provider order entry (CPOE), clinical decision support systems, electronic health records (EHR), and e-mail communication with patients [37]. Along with these technologies, a wide variety of other devices, tools, and instruments are used to support clinical work.

Activities (required achieving a goal). Clinical work aims at taking care of and curing patients. Although physicians share this objective of work, the individuals have diverse and dynamic working practices, numerous communication and interaction routines, and ways of using ICT systems. In more detail, these practices are concerned with rapid task completion and relevant information access, and for example the habits of managing clinical documentation vary depending on the working environment and the task at hand [38]. Furthermore, information exchange and communication between healthcare professionals are essential parts of clinical work and daily tasks. As pointed out by Karasti et al. some of these aspects of work are hidden by nature, and needs to be carefully studied and understood since they are valuable to the success of technology-supported caring process [39]. As a consequence, Bardram et al. have described the following characteristics of healthcare work that needs 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 [40].

Environment. The surroundings in which healthcare 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 (e.g. wards, operation rooms, control rooms, emergency department, clinics, etc.) have special characteristics when physical, organisational (including organisational structure, rules and division of work), and social aspects (such as cultural models and attitudes) are considered. Similarly, these environments include various actors and collaborators: physicians and nurses, other care workers, healthcare administrators, patients and their supporting parties. For example, compared to wards in healthcare centres, in hospitals in emergency departments the social environment is characterised by highly collaborative and well-coordinated actions between the professionals.

4.2. *Aspects of usability in the questionnaire for physicians' clinical work*

The components of clinical context of use, described in the previous chapter, do not as such provide sufficient information about the contexts specific attributes or dimensions of usability but indicate what kind of empirical data should be gathered regarding the user and ICT system characteristics, and places of clinical work. Arising from the need to design usability questions for our questionnaire study, we utilized the definition of usability presented in the ISO standard [16] (illustrated

in Fig. 1) as a starting point in analysing and describing the themes for the questionnaire, hence it was seen to approach usability issues from a broad perspective and be generally well-known and widely cited. Finally, we ended up describing three aspects of usability, which we considered important to be included in the questionnaire and which would reflect the characteristics of physicians' clinical work. The following chapters describe these three aspects, further referred as usability dimensions of clinical ICT system usability.

Dimension 1: Compatibility between clinical ICT systems and physicians' tasks. Following the ISO 9241 standard [16], the starting point of the analysis work was to identify the *user's main goals* and support users in achieving these goals with a pleasant user experience. The primary goal of physicians' work in clinical environments can be described as follows: take care of and cure patients. The technology environment, when considered as a whole, is to serve this ultimate goal: to support physicians and other healthcare workers in clinical activities. Thereby, one perspective on usability is to evaluate the compatibility between clinical ICT systems and physicians' tasks. This perspective is closely related to two well-known principles of user-centred design: "understanding the user characteristics" and "system suitability for the task" [15]. In order to support meaningful use, ICT systems need to be integrated into physicians' working procedures instead of forcing them to adapt new processes or perform additional tasks.

In a more concrete level requirement for compatibility can be seen to cover issues of *need for appropriate functionality* and *efficiency of task performance*. The systems should provide the physicians those functionalities and properties that are needed to perform key clinical caring tasks with patients, e.g. analyse the current state, make decisions about the needed actions, and conduct these actions. As pointed out by several studies, one of the most significant barriers in healthcare information technology adoption is concerned with the amount of time it takes to use the system (e.g. [41–44]). Thereby *efficiency* refers to the accuracy and completeness with which physicians achieve their goals: clinical ICT systems need to be efficient to use so that a high level of productivity in a hectic and critical healthcare environment is possible. In clinical work, the requirement for efficiency especially relates to the fluency of information management, hence complete and accurate documentation is said to be a central focus in the effort to improve patient safety and healthcare quality [45]. However, empirical studies have pointed out that time taken up by clinical documentation is one of the most challenging bottlenecks of EHR use (e.g. [46–49]). The amount of interaction steps required in both record-keeping and information retrieval activities should be optimal. Additionally, there should not be a need to perform the same task or data entry multiple times.

In the user-interface level compatibility can be seen to refer to *intuitiveness of user interfaces* and reflect the success of user-interface design. Without a doubt, healthcare professionals tend to be extremely busy. Clinical physicians do not have time to read manuals or otherwise get familiar with new systems. Instead, they need to be able to rapidly start getting the work done in the way it is supposed to be done without errors. Therefore, ICT systems should have intuitive user interfaces, meaning that the user interface, including all components of an interactive system that provide information and controls for the user to accomplish specific tasks with the interactive system [16,23], should be immediately understandable without the need for the initiation of special educational measures [50]. These kinds of usability issues are typically addressed in established usability questionnaires (e.g. SUMI [51] and SUS [52]).

Dimension 2: ICT support for information exchange, communication and collaboration in clinical work. Among others, Lenz et al. [53] have pointed out that clinical processes share characteristics that are only typical for the healthcare delivery domain: a high degree of communication and cooperation among professional workers. Furthermore, Nobel [54] supported by several other researchers (e.g. [17,36,39,40]) has proposed transfer of information, coordination of activities, and communication among healthcare workers being the salient characteristics of healthcare work when ICT development is concerned. These arguments indicate that it is not enough for the clinical ICT systems to serve a single user, but instead they should support communication and collaboration between numerous parties. This can be illustrated by thinking clinical work from the patient's perspective. Patients are at the centre of clinical work and the network of healthcare actors. The personnel around patients, including physicians and nurses, aim at effective results in an efficient way. Communication between these stakeholders, working at different locations and shifts, affects the effectiveness and efficiency of clinical work. Additionally, collaboration often takes place in an ad hoc manner, which leads to frequent interruptions of workers. Therefore, intensive information exchange is dependent on situational information and changing contexts. According to empirical study findings, the success of healthcare information systems depends on the quality of the information available to healthcare professionals in making decisions about patient care and in the communication between healthcare professionals during patient care [55]. Also, Walsh has argued poor communication being more often detrimental to patient than lack of knowledge [56].

Another viewpoint on collaboration relates to patient's role as collaborators. Today, patients cannot be considered as passive stakeholders. Instead, the ideology of patient-centred care challenges the traditional ways of delivering care; the processes need to focus on communication, collaboration, and shared decision making with the patient [57–59]. The applications of digital technologies are already extending the reach of hospital care into the community and into the home. Patient health record systems (PHRs) can increase a patient's awareness of her health and help in making informed decisions. The access to one's own health information could motivate patients or their supportive parties to actively participate in treatment. By sharing information and using ICT systems collaboratively, physicians could interact with patients in a smoother way in their office, patient's bedside, or in home-care environments. All these issues support the aim of clinical ICT systems providing support for information exchange, communication and collaboration.

Dimension 3: Interoperability and reliability. At present, issues of *interoperability* and integration of separate healthcare systems remain generally unsolved (e.g. [41,60–62]). A lack of

interoperability between healthcare systems and devices has even been shown to slow the workflow of healthcare professionals [60]. *Reliability* and *technical functionality* are without a question important in life-critical environments. From the physician's viewpoint, it is extremely important that ICT tools are reliable and fit to the existing technology environment. Consequently, the requirement for technical feasibility can be seen to cover integration, information flow and compatibility between systems, as well as the diversity of applications and technologies in use (information systems, mobile application, and wireless technologies).

With regards to components of clinical context of use (described in Section 4.1) the first dimension *Compatibility between ICT systems and physician's tasks* is closely related to the components of *user*, *activities* and *systems*, whereas the second *ICT support for information exchange, communication and collaboration in clinical work* to *activities*, specific characteristics of physician's work, and *social environment* with numerous collaborators. The third dimension *Interoperability and reliability* emphasises the technology aspects of context of use: *systems* and the *physical environment* (particularly attributes of the wider technical [16]). In addition to these three dimensions, one interesting perspective on clinical ICT system usability derives from the fact that the *organisational environments* in which the systems are used vary considerably. When thinking about the wide variety of physical and organisational environments, as well as assorted clinical tasks associated with those, one may understand that clinical ICT applications should be flexible in terms of their use – they need to adjust to numerous clinical environments. Similarly, healthcare organisations as well as individual workers should be able to customise the systems to support their specified needs. As could be expected, these needs in hospitals are far more complex than in healthcare centres.

To conclude, from the viewpoint of physicians', clinical ICT systems are expected to have a positive impact on patient care and thereby improve healthcare delivery by supporting operational tasks and goals. For the purposes of our national questionnaire study with clinical physicians, the usability of clinical ICT systems were described to cover the following aspects:

> *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 organisational settings.*

In the empirical study, these dimensions were used to guide the questionnaire design and analysis of data. The following chapters describe the study procedure and gained results.

5. Questionnaire study with physicians in Finland

In Finland, ICT is widely used in healthcare. Finnish healthcare professionals are generally considered to have good ICT skills due to the capacity that has been build through undergraduate and postgraduate training in ICT, continuing education in ICT and eLearning in health sciences [63]. Electronic health record (EHR) systems presently cover 100% of the specialised and primary healthcare organisations (hospitals and healthcare centres) [64]. As a result of progress in electronic information exchange between organisations, fully interoperable patient data exchange is regionally in operational use in most of healthcare institutions [64,65]. Further, the already comprehensive basic IT infrastructure in healthcare is seen as a strong area in the further development of eHealth [66]. At present, a national archive for electronic healthcare data with citizen access is under development. The aim is to create a new working environment for professionals by incorporation of innovative ICT and to offer citizens the possibility of actively participating in decisions on their care [67]. However, several challenges relate to implement the norms, standards and interoperability of ICT as healthcare providers are decentralised [65].

Similar to other industrialised countries, the effects of new technology adaptation seem to be manifold in Finland. The success of healthcare information systems is an ongoing topic of discussion. Several national studies have pointed out both advantages and serious challenges in technology adaptation and use in clinical settings [e.g. 68–71]. Our national questionnaire study aimed at contributing to these discussions and supporting the further development of the systems.

5.1. *Research method: usability questionnaire*

Although usability research is characterised as a highly qualitative research approach, questionnaires are often applied with the objective of identifying the remaining problems and to evaluate whether the target values for quality of use have been achieved [72]. According to Kirakowski [73], the main advantages of using questionnaires in usability research are that they provide (a) feedback from the point of view of the user, (b) data from a large group, and (c) a quick and cost-effective method for data gathering. Questionnaires can also be applied for user and task analysis with the purposes of broadening the initial findings to the entire population, evaluating representativeness in a wider user group, and further investigating research findings [74]. On the other hand, designing a good survey is difficult. Misinterpretations might occur due to awkwardly phrased questions or the mismatch between the questionnaire contents and the user's prevailing surroundings, mood and interests [74]. Accordingly, to be able to develop closed questions for a questionnaire, researchers need to know the critical questions and all the possible answers.

There have been few attempts to develop usability questionnaires for product and software evaluation. Established questionnaire resources include quantitative and qualitative, mature and new, and commercial and public questionnaires

with standardisation databases. Four widely known and applied usability questionnaires, SUMI (Software Usability Measurement Inventory) [51], SUS (System Usability Scale) [52], QUIS (Questionnaire for User Interaction Satisfaction) [75] and USE (which stands for Usefulness, Satisfaction, and Ease of use) [76], share several aspects in common. They (a) focus on a selected software, system or workstation, (b) evaluate the usability of a user interface, and (c) are context and domain independent. As pointed out by the John Brooke, the developer of the SUS usability questionnaire, measures of usability must of necessity be defined by the context in which the artifact is used [51]. This statement emphasises challenges in applying and adjusting established usability questionnaires in research of ICT in healthcare.

Relatively little can be found from the literature about usability questionnaires in the healthcare field. The starting point of our questionnaire study was different from others [e.g. 12–14], since we aimed at researching the usability of the clinical ICT systems from the viewpoint of physicians' and their clinical tasks. In early phases the of study design, it became clear that, for the purposes or our research, the established usability questionnaires as well as the proposed definitions for usability of healthcare ICT had their limitations. For these reasons, widely used usability questionnaires, for example SUMI [51], were found to be inadequate for our application. Additionally, the aim of our study was not only to identify the current problems, but to address the development of ICT systems.

5.2. *Procedure of the study*

Our questionnaire was targeted to Finnish physicians, who are under 65 years and actively engaged with clinical work in healthcare centres or in public secondary and tertiary care hospitals [77]. The study was designed by a multidisciplinary group, whose seven members are experts in the areas of usability research, medical informatics, sociology of technology, medicine and medical practices, and occupational health research. The questionnaire incorporated several ICT use-related research themes: usability, information system success, user-centred ICT development, and occupational health.The web-based questionnaire was designed in an iterative manner and included two pilot testing phases. The finalized questionnaire was in Finnish and included in total 38 questions. Only a few of the questions were obligatory since the researchers wanted to provide the physicians a feasible way to contribute to the study.At the beginning of the questionnaire, there were 16 questions regarding the clinical physicians' backgrounds (e.g. questions about age, gender, working sector, fields of specialisation) and their experience in using healthcare systems (e.g. the name of the principally used EHR system, an estimation of the amount of time the respondent has used the system). The usability-related questions were formulated based the previously described usability dimensions and included the following (the statements are presented in details in Table 4):

- 13 statements addressing *dimension 1: compatibility between clinical ICT systems and physician's tasks*. Of these, four statements were related to key functionalities, three to the efficiency of task performance, and six to the usability of EHR user interfaces.
- 12 statements addressing *dimension 2: ICT support for information exchange, communication and collaboration in clinical work*. Of these, five were related to information exchange within and between healthcare units and organisations. The rest of the statements addressed the collaboration between various stakeholders: physicians, nurses, and patients.
- Seven statements addressing *dimension 3: interoperability and reliability.* These statements included issues of system failures, interoperability, accessibility, reliability, and the ability of physicians to recover from technical problems.
- *A summative multiple choice question* about the overall ratings using a school grade (on a scale from 4 or fail to 10 or excellent) given to EHR systems. This question summarised the respondent's experiences and opinions on their principally used information systems with references to other previously answered statements.

5.3. *Data gathering and analysis*

The web-based questionnaire was available from mid-February to mid-March 2010. During that time, 3929 physicians, representing one third of the physicians working actively in the clinic in Finland, replied to the email invitation sent by the Finnish Medical Association.

The sample could be said to be representative of the population [77]. The representativeness of the sample was assessed by comparing respondents' age, gender and working sector distribution to all Finnish physicians' demographics held by the Finnish Medical Association register. As a result of this analysis, no statistically significant differences were found.

The data for usability analysis incorporated 32 statements with answers given using a five-point Likert-scale and one multiple choice question about the overall EHR rating with a scale from 4 to 10. The interpretation of research data followed the usability dimensions and accordingly classified statement items. Statistical analysis was conducted using SPSS 17 software.

The large research data made it possible to explore differences between responses from carious healthcare organisations. Therefore in the analysis questions about physicians' backgrounds (working sector and healthcare organisation) were used as background variables in the cross-tabulation analysis of the usability statements addressing the dimensions 1–3. Also, the summative question about the overall ratings for EHR systems were analysed similarly for the purposes of gathering data about the clinical ICT system's abilities to adjust to various clinical environments and users' needs.

6. Usability results

We have divided the results into six sections. After illustrating the respondent demographics (Table 1), we briefly introduce the EHR systems with respect to the overall ratings (school grades) given to them (Tables 2 and 3). Next, we report the questionnaire results following the usability dimensions (Table 4) and findings on differences between the responses

Table 1 – Respondent demographics (N = 3929).

Gender, %	
Female	57.8
Men	42.2
Age, %	
<34 years	12.1
35–44 years	23.6
45–54 years	35.3
>55 years	29.1
Healthcare sector, %	
Public hospital	49.6
Public healthcare centre	23.4
Other (private providers)	27.0

from various institutional settings (specifically hospitals and healthcare centres) (Tables 5 and 6).

6.1. *Respondent demographics*

In total, 3929 physicians responded the web questionnaire. Hence, the response rate to our study was 31.3% (the total number of physicians in Finland in clinical work is 14,411 and the register of email addresses from the Finnish Medical Association covered 95% of them [77]). Respondent demographics showed that 57.8% of the respondents were women and 42.2% were men (Table 1). Almost half of the responding physicians were working in public hospitals, whereas 23.4% were in public healthcare centres and 27.0% in other healthcare organisations (private providers of healthcare services).

6.2. *Physicians' overall ratings for their EHR systems*

Physicians' estimates of their EHR systems were very critical (Table 2). Given the rating scale from 4 or fail to 10 or excellent, the average of the marks varied from 6.1 to 8.4 dependent on the kind of facility where the physician is working. Analysis revealed that dissatisfaction with EHR systems was highest in the municipal sector (public hospitals and healthcare centres). Only system A got a grade over 8. This system has a small user population and is used in a specific healthcare context – in the health service of university students. Systems with larger user populations (in total about two thirds of all physicians engaged in clinical activities in Finland), such as systems E, J and I, got relatively low ratings (averages were between 6 and 7). E and I are used both in public specialised healthcare (hospitals) and primary healthcare centres, whereas J is used only in public specialised healthcare.

Table 2 – Physician's overall ratings for their principally used EHR systems [77].

EHR system	Healthcare sector in which the system is used	Respondents (*N*)	Mean opinion score (4–10)	Std. deviation
A	Private providers of healthcare services	36	8.4	1.2
B	Private providers of healthcare services	74	7.2	1.0
C	Private providers of healthcare services	258	7.2	1.0
D	Public hospital	154	7.2	1.2
E	Public healthcare centres and hospitals	632	6.9	1.1
F	Public healthcare centres	37	6.9	1.3
G	Private providers of healthcare services	54	6.7	1.2
H	Public healthcare centres and hospitals	110	6.3	1.6
I	Public healthcare centres and hospitals	350	6.2	1.2
J	Public hospitals	610	6.1	1.2
Other		167	6.6	1.4
Total		2482	6.6	1.3

Table 3 – Cross-tabulation between respondents' demographics and overall ratings for EHR systems [77].

	Respondents (%)	Mean opinion score (4–10)	Std. deviation	% of grades 4 and 5	% of grades 9 and 10
All	100	6.6	1.3	19.7	5.2
Gender					
Female	58.9	6.7	1.2	16.2	4.5
Men	41.1	6.5	1.4	24.7	6.3
Age					
<34	13.3	6.4	1.2	22.3	3.0
35–44	24.2	6.6	1.2	19.7	3.5
45–54	34.7	6.7	1.3	17.3	6.1
>55	27.7	6.7	1.3	21.2	6.9
Experience					
<1/2 years	6.9	6.1	1.2	30.0	0.6
1/2–1 years	4.9	6.4	1.2	25.4	1.6
1–3 years	23.8	6.4	1.2	22.9	3.1
>3 years	64.4	6.8	1.3	17.1	6.9
Healthcare sector					
Hospital	49.1	6.4	1.3	24.5	3.1
Healthcare centre	23.6	6.7	1.2	15.9	4.4
Other	27.4	7.0	1.3	14.4	9.7

Table 4 – Summary of questionnaire items (usability statements) and clinical physicians' responses.

Item no.	Statements	Strongly agree %	Agree %	Neutral opinion %	Disagree %	Strongly disagree %
Dimension 1: Compatibility between clinical ICT systems and physician's tasks						
Key functionalities						
1	Systems provide support for decision making (reminders and warnings) (N = 3817)	4	18	27	29	21
2	Systems help to prevent medication errors (N = 3812)	3	25	20	29	22
3	EHR provides a proper summary view (daily treatment chart) about the situation of the patient (N = 2153[a])	1	7	9	19	19
4	Systems help to improve health outcomes (N = 3848)	6	29	30	23	12
Efficiency of use						
5	Routine tasks can be performed in a straightforward manner using the EHR system (N = 3882)	9	27	14	29	21
6	Systems require me to perform a fixed sequence of tasks (N = 3851)	24	38	20	15	3
7	I find it easy and fluent to manage patient information (document and retrieve data) using the information systems (N = 3835)	5	23	18	36	18
Intuitiveness of EHR user interfaces						
8	The EHR system responds quickly enough to inputs (N = 3873)	9	38	16	27	10
9	I perceive the arrangements of the fields on-screen as sensible for the work I do (N = 3857)	8	35	18	26	12
10	The EHR system provides me appropriate feedback about the tasks it performs (e.g. when saving data) (N = 3871)	7	30	22	30	12
11	The terms and concepts used in the EHR system are clear and unambiguous (N = 3870)	9	39	19	23	9
12	I find it easy to learn how to use the EHR system (N = 3881)	14	40	16	20	10
13	Learning the use the EHR system does not require long training (N = 3877)	10	34	20	24	12
Dimension 2: ICT support for information exchange, communication and collaboration in clinical work						
Support for information exchange						
14	Information about the laboratory results are presented in a logical format (N = 3799)	14	50	15	15	6
15	Nursing information is easily accessible and readable (N = 3642[b])	5	28	14	27	21
16	Patient's medication list is clearly presented (N = 2999[c])	3	17	13	22	24
17	Information about the patient's medication from other organisations is easily accessible (N = 3766)	1	4	9	25	60
18	Delivery of patient information from other healthcare organisations often takes too long time (N = 3760)	46	28	12	8	6
Support for collaboration						
19	ICT systems support in achieving continuity of care (N = 3854).	6	36	27	22	9
20	ICT systems support collaborative activities between physicians working in the same organisation (N = 3868)	14	50	17	14	5
21	ICT systems support for physicians in cross-organisational collaboration (N = 3819)	1	12	16	36	34
22	ICT systems support collaboration between physicians and nurses (N = 3821)	6	37	23	25	9
23	ICT systems help to monitor reception of orders and instructions I have given to nurses (N = 2287[d])	1	6	14	16	24
24	ICT systems support collaboration between physicians and patients (N = 3772)	2	12	31	28	28
25	ICT systems often capture attention away from patients (N = 3872)	24	40	14	18	4
Dimension 3: Interoperability and reliability						
26	Logging into several systems takes too long time (N = 3857)	43	33	9	12	3
27	I have easy access to radiology results (N = 3799)	11	38	16	23	11
28	The EHR system is reliable and stable, and no system errors (e.g. crashes) occur when I work with the system (N = 3886)	11	44	12	25	8
29	I feel that occasionally some of the data I have entered disappear from the information systems (N = 3832)	9	21	23	32	14
30	If I have problems with EHR system, I can easily get help or recover from error situation (N = 3866)	11	39	22	21	7
31	A significant portion of my working time is wasted on struggling with technical problems (N = 3868)	14	28	23	27	8
32	Incorrect functionality has or nearly has caused serious injury to a patient (N = 3825)	14	18	27	26	15

[a] 44% of the respondents reported being short of this functionality.
[b] 5% of the respondents reported being short of this functionality.
[c] 21% of the respondents reported being short of this functionality.
[d] 39% of the respondents reported being short of this functionality.

Table 5 – Comparison of physicians' overall ratings for EHR systems used in public healthcare centres and hospitals [78].

EHR systems	Healthcare sector in which the system is used	Respondents (*N*)	Mean opinion score (4–10)	Std. deviation
E	Public healthcare centres	274	7.1	1.1
E	Public hospitals	289	6.7	1.1
H	Public healthcare centres	34	6.9	1.5
H	Public hospitals	51	5.6	1.3
I	Public healthcare centres	231	6.2	1.2
I	Public hospitals	60	6.1	1.2

It is worth noticing that only 2484 respondents out of 3929 responded to the question of overall rating for the EHR system. Despite the missing data from one in three respondents, there were no significant differences between respondent demographics or EHR systems and the missing answers [77].

Cross-tabulation between the respondents' demographics and overall EHR ratings revealed interesting findings (Table 3). In the questionnaire study, females gave slightly better grades than men. Physicians over the age of 45 seemed to be more satisfied with the systems than younger ones, especially when it came to the total number who gave grades of 9 or 10. Respondents with more than three years experience on using their EHR system gave better grades than novice users. On the other hand, almost 90% of the respondents had more than one year of experience using the principally used system. The analysis also indicated a variance between institutional settings and their clinical environments. Physicians in hospitals were less satisfied with the EHR systems than their colleagues in healthcare centres or other organisations, and physicians in private clinics were most satisfied with their systems.

6.3. *Compatibility between clinical ICT systems and physician's tasks (dimension 1)*

According to the study results (Table 4), currently used clinical ICT systems lack appropriate features. About half of the respondents disagreed with the statements about the systems' abilities to support decision making and to provide help for preventing medical errors (statements 1 and 2). Additionally, 44% of the respondents did not have a summary review functionality integrated into their EHR system and only 1% strongly agreed and 8% agreed with the statement about their EHR system providing an appropriate summary view (daily treatment chart) about the patient's health and problems (statement 3). Responses on the question of the systems' abilities to improve health outcomes (statement 4) were distributed almost evenly between agree, neutral, and disagree opinions.

Physicians expect their clinical ICT systems to provide better support for performing routine tasks than they currently do. In total, half of the respondents disagreed with the statement about EHR system's support for performing routine tasks (statement 5). Similarly, 62% of the physicians felt that the systems hinder their work by requiring them to perform a fixed sequence of steps (statement 6). The results also indicated that information systems are poorly suited to the requirements of information management tasks (with statement 7).

Compared to statements about key functionalities and efficiency of task performance, questions about the characteristics of EHR user interfaces addressed issues of human–computer interactions in more detailed level. In general, physicians expressed rather positive opinions about the user interface characteristics and intuitiveness of EHR use. Most of the respondents agreed with the positively formulated statements on feedback, screen layout, and terminology (statements 8–11). Again, answers to the statements referring to learnability (statements 12 and 13) followed the tradition of rather positive experiences.

Table 6 – Examples of questionnaire items with a comparison of responses from divergent healthcare sectors. All differences are statistically significant ($p < 0.001$) [77].

Statements	Agree %	Neutral opinion %	Disagree %
Systems require me to perform a fixed sequence of tasks (statement 6)			
Public hospital (*N* = 1925)	68	20	12
Public healthcare centre (*N* = 908)	59	19	22
Other (*N* = 1018)	54	21	26
I find it easy and fluent to manage patient information (document and retrieve data) using the information system (statement 7)			
Public hospital (*N* = 1917)	22	18	60
Public healthcare centre (*N* = 913)	29	19	53
Other (*N* = 1005)	39	18	42
Incorrect functionality has or nearly has caused serious injury to a patient (statement 32)			
Public hospital (*N* = 1908)	43	27	31
Public healthcare centre (*N* = 902)	28	29	43
Other (*N* = 1015)	15	24	61

6.4. *ICT support for information exchange, communication and collaboration in clinical work (dimension 2)*

Results on the clinical ICT systems' abilities to support information exchange indicated both positive and negative findings. Most of the physicians were satisfied with the presentation of laboratory results in their systems (statement 14). However, half of the respondents disagreed with the statements (15 and 16) on accessibility and availability of nursing and patient's medication information when performing clinical tasks.

Statements on accessibility and delivery of patient information between healthcare organisations resulted in notably negative results. Of all respondents, 85% disagreed with the statement on easy access to a patient's medical information that has been documented in other healthcare organisations

(statement 17). Likewise, problems with the time taken up by cross-organisational exchange of information were a critical issue (statement 18).

Findings on ICT support for collaboration showed mixed results. Sixty-four percent of the respondents were satisfied with the current systems and their support for collaboration and information exchange within their own organisation (statement 20). By contrast, significant portion of respondents claimed that the systems poorly support collaboration between the physicians working in distant locations (statement 21) and physician–nurse collaboration (statements 22 and 23).

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. More than half of the respondents had the opinion that technology supports collaboration poorly, whereas every third did not have an opinion (statement 24). Similarly, 64% felt that the use of computers often captures the physicians' attention away from the patient and her care (statement 25).

6.5. *Interoperability and reliability (dimension 3)*

Following from the previously described findings, the results on the technical aspects of healthcare ICT usability indicated contradictory observations. Seventy-six percent of all respondents argued that too much time was taken up by logging into several systems (statement 26). However, another statement addressing the interoperability of the healthcare technology environment reflected rather positive results: about half of the physicians had easy access to radiology results (statement 27). About half of the respondents agreed or strongly agreed with the statement "the EHR system is reliable and stable" (statement 28). However, the efficiency of use was hindered by the disappearance of documented data. As an illustration, as many as 30% of all respondents felt that, occasionally, some of the data they entered mysteriously disappeared (statement 29).

Half of the respondents were rather satisfied with support for recovering from error situations (statement 30). Interestingly, however, they also argued that technical problems hinder their work significantly and require a lot of resources (statement 31). Perhaps the most alarming result of the questionnaire study was that almost one third of the respondents agreed or strongly agreed with statement 32 about systems' incorrect functionality having caused or nearly having caused serious injury to a patient.

6.6. *Differences between responses from various healthcare organisations*

The contexts in which clinical ICT systems are used are many. As illustrated in Table 2, three of the researched EHR systems are used both in public hospitals and healthcare centres (systems E, H and I). The further analysis of questionnaire results indicated differences between responses from public hospitals, public healthcare centres, and other organisations (private providers of healthcare services). The following exemplary samples are to illustrate these differences.

Cross-tabulation analysis between the school grades and the respondents' healthcare organisations indicated variances in the given grades (Table 5). Mean grades for system I appeared to be about the same (6.2–6.1). On the other hand, systems E and H seemed to be notably better suited to the requirements of healthcare work in healthcare centres than in hospitals (the averages were 7.1 against 6,7 and 6.9 against 5.6, respectively).

The study results also indicated that physicians working in public hospitals seemed to be more critical of ICT systems and their abilities to provide support for routine tasks, compared to healthcare centre physicians. This finding was illustrated by the analysis of a few selected statements (Table 6). For the sake of simplification in Table 6, the Likert-scale answers "strongly agree" and "agree" were combined to form the category "agree" and similarly "disagree" and "strongly disagree" were combined to form the category "disagree".

The illustrated examples show that poor support for work routines and difficulties with the management of patient information were emphasised by the physicians in hospitals (statements 6 and 7 in Table 4). Especially, differences between the responses from various healthcare sectors were highlighted with statement 31 "System failures have or nearly have caused serious injury to patient", of which almost one third of all respondents agreed. Within the respondents working in public hospitals, this percentage was even higher: 43% of them agreed with this statement (whereas in public healthcare centres 28% and in other organisations 15% of users agreed with this statement).

7. Discussion

This chapter presents the main contribution of the research, describes the challenges of designing a usability questionnaire, and discusses the relevance of the research and study limitations.

7.1. *The main contributions*

This paper aimed at researching the usability of clinical ICT systems and increasing the understanding usability aspects in the context of clinical work.

7.1.1. *Critical findings on clinical ICT system usability*

To support healthcare delivery, ICT systems need to be effective, efficient, easy to learn, and furthermore have a low error rate. Our usability study pointed out several serious problems and deficiencies which may considerably hinder the efficiency of ICT use and physician's routine work.

Questions on the compatibility of ICT systems with physicians' tasks indicated the need for a proper patient overview chart (daily treatment chart) feature, as well as better technology support for decision making and the prevention of medical errors. At present, ICT systems require physicians to perform fixed sequences of steps and tasks, and poorly support the management of patient data.

On the other hand, physicians had rather positive opinions about the usability of user interface characteristics, e.g. regarding terminology, feedback and learnability. The usability

analysis showed notable differences between the investigated EHR systems, especially when it comes to the question of intuitiveness of user interfaces. This is easily understandable since the overall grades given to EHR systems varied significantly. However, the positive opinions seem to be somewhat contradictory with earlier usability studies and raise questions for further research regarding the applicability of questionnaire method and user's abilities to evaluate the usability of those systems they have used for a rather long period of time.

Based on the study results, clinical ICT systems do not seem to sufficiently support information exchange or collaboration. Among the most general problems were difficulties in accessing patient information from other organisations. Most of the respondents were satisfied with the support ICT systems provide for collaboration between co-located physicians; nevertheless, their opinions regarding cross-organisational communication as well as physician–nurse and physician–patient collaboration were critical. Two of the three respondents even argued that the systems unintentionally captured attention away from patients.

The results on interoperability and reliability showed that physicians suffered from lack of integration between principally used systems and system failures. What is more, every third physician estimated that a malfunction of the information system had posed a risk to patient safety.

The analysis also indicated that, in general, physicians working in hospitals were more critical towards clinical ICT systems than their colleagues in healthcare centres or other organisations. In this article, however, deeper analyses of the contextual findings as well as differences between EHR systems were intentionally left out of the scope.

Several of our findings have been supported by earlier usability studies [e.g. 4,6]. Previous research has shown problems in data entry [46–49] and inadequacies in integration between EHR and other systems [60,62]. Our finding on hospital physicians being more critical than their colleagues in healthcare centres is consistent with those of Christensen et al. [79]. These findings indicate that physicians in hospitals and healthcare centres have different requirements and needs towards the information systems and that the currently used systems are less suited to hospital contexts. The results also showed that physicians' estimates about the EHR systems used in private healthcare provider organisations were more positive compared to systems used in public sector. In Finland, these private providers include mainly clinics with speciality areas such as occupational health, general practice, psychiatry, and gynaecology.

7.1.2. *Contextual dimensions of clinical ICT system usability*

The definitions for the concept of usability (presented in Section 3.1) reflect the multidimensional nature of usability work: some can be considered as rather abstract (e.g. [30,32]) while others are detailed with specific focus on user-interface characteristics (e.g. usability attributes described by Nielsen [23] and ISO standard [15,16]; some emphasise an evaluation approach (e.g. [23]) while others are more design-oriented (e.g. ISO standard [15,16] with references to contextual and experimental aspects of usability). Furthermore, the definitions emphasise the need for understanding usability as a contextual property – meaning that the objectives of research and usability considerations should reflect the characteristics of the contexts of use in which the interactive systems are used.

For the purposes of our questionnaire study for physicians' clinical work, we described three dimensions of usability and further applied those in an empirical study. The dimensions were: (1) compatibility between clinical ICT systems and physician's tasks, (2) ICT support for information exchange, communication and collaboration in clinical work, and (3) interoperability and reliability. In addition, it is important that clinical ICT systems adjust to various clinical environments, since the characteristics of physicians' tasks and organisational environments vary considerably. The usability dimensions were derived from the definitions of usability, especially from the widely known one (the ISO 9241 standard [15,16]), and the characteristics of clinical physicians' work.

7.2. *Challenges in usability questionnaire design*

In order to design a usability questionnaire for physicians' clinical work the researchers need to understand the contextual aspects behind: characteristics of physicians' work and working contexts, as well as the variety of organisational environments. In the early phases of our study, the most pressing challenges were related to the questions of what should be studied. We did not only want to provide a generalized picture about the current usability problems of clinical ICT systems, but also wanted to address the development of the systems. Compared to typical usability studies in health informatics field, we approached the study subjects from a broader viewpoint. For our purposes, the widely used usability questionnaires, for example SUMI [51], were found to be inadequate for application as such. What is more, the physicians appeared to be an extremely heterogeneous target group and were therefore difficult to study using a standard questionnaire. The questionnaire had to be designed in a way that took into account various areas of expertise, places of work (clinical units, as well as private–public and specialised-primary sector characteristics), numerous ICT systems, and the variety of physicians' work practices.

Compared to established usability questionnaires a tailor-made questionnaire can be seen to have several advantages. When designing a questionnaire and addressing usability as a generic, non-contextual property, the following challenges arise. First, we assume that respondents are able to determine what the concepts of "ease of use" or "easy location of information" cover. Without sufficient understanding, it is difficult to decide what kind of characteristics or viewpoints should be considered when answering these questions. Typically, respondents do not have experience in the use of competitive systems or most modern technologies at the workplace, which makes it difficult to determine the levels of expectations towards desired new applications. Moreover, respondents may get an impression of questions as dealing with both the functionalities of the particular system and the capabilities and abilities of them as user. Thus, respondents may be reluctant to give negative values to questions of ease of use and learnability. What is more, questionnaire studies typically address usability at an abstract, not context-sensitive level. For exam-

ple, statements about "ease of use" or "ease of learning" in our study could have included numerous aspects: use of several systems, work with the systems in a hectic environment, need for support and training, access to laboratory and radiology results, fluency in searching and documenting patient information, ability to get support in decision making, etc. It is often unclear which of these aspects the respondents have in mind when giving answers. These limitations should be carefully considered when designing a usability questionnaire study.

7.3. *Relevance of the research*

In the human–computer interaction (HCI) field, more and more research is conducted around the concept and phenomenon of "user experience". According to recent discussion and publications, user experience (UX) can be considered as "sibling of usability" although the relation and distinction between these concepts is not completely clear. This has for example been presented in ISO 9241-210 standard [16], in which a note points out that there is a misconception that usability refers solely to making products easy to use making UX more versatile and applicable for comprehensive analyses regarding user viewpoint in development. In relation to these discussions and the evolving field of user experience research, it is easy to argue that the focus we had in our study – research the physicians' experiences on usability of clinical ICT systems – is well-argued and highly relevant. Furthermore, the described usability questionnaire for physicians' clinical work can be seen to present a methodological contribution to the usability research field.

Our usability study 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 studies addressing end-users' experiences on the usability of numerous ICT systems in clinical settings. First, the described three usability dimensions which reflect the characteristics of physicians' clinical work in the context of using numerous ICT systems are to inform researchers about context specific aspects of usability. Previously no such usability dimensions had been introduced in the fields of health informatics or usability research. Furthermore, the paper presented novel results on the current state of clinical ICT systems usability. To our best knowledge, this type of national usability study with nearly 4000 respondents has not been conducted in any other country in which healthcare technologies have been widely adopted. Although the overall response rate was not notably high (31.3%) the number of responses could be considered to be outstandingly high, particularly compared to usability evaluation studies in the field.

7.4. *Limitations of the study*

The questionnaire study was designed and conducted by a multidisciplinary group. This arrangement was seen as necessary for the following reasons: (1) to guarantee that the included research themes (usability, information system success, user-centred ICT development, and occupational health) were covered in an appropriate way and (2) to make sure that from the physician's perspective the questionnaire would be reasonable and credible, and include all the relevant questions. According to our experiences, the physicians' contribution was highly valuable. During all the stages of study development, physicians' viewpoint was actively involved and acknowledged. The questionnaire study was coordinated by a physician actively engaged with patient work, and additionally two other study group members were experts in medical practices. In addition, several physicians participated the pilot-testing activities. However, the process of questionnaire design did not include reliability testing. Although in our study the number of responses is considerably high ($N = 3929$), the importance of these activities should not be underestimated. In Finland, the questionnaire study is to be repeated regularly every few years. This future work around the developed and applied usability questionnaire for physicians' clinical work should include e.g. reliability testing as well as factor or regression analysis to find out which usability questions contributed to the final grades given to EHR systems or to see how the described usability dimensions are seen in the data.

Compared the other usability methods, a questionnaire is a suitable technique for gathering information from a large group of users. Nevertheless, when researching usability and physicians' experiences using a questionnaire method, several limitations need to be pointed out. Firstly, the usability questionnaire reports on subjective experiences which reflect the respondent's earlier experiences, characteristics of a situation in which she answers the questions, and tasks she has recently performed. Therefore, the objectivity of the results can be easily questioned although the study would have had numerous respondents. On the other hand, the subjectivity of the questionnaire method can also be considered as being an advantage. Typically usability methods, for example expert reviews and usability tests, aim at researching usability from an objective viewpoint but similarly may have difficulties in gathering data and understanding the current problems from the end-users' viewpoint. Compared to these methods and study setups, a carefully planned questionnaire can have the ability to provide the end-users' a unique means of communicating their experiences about the ICT usage as well as for the researchers to receive valuable data from the viewpoint of end-users.

Secondly, designing a questionnaire study is extremely difficult and requires in depth knowledge about both usability research issues as well as domain specific characteristics and end-users' contexts. Our questionnaire study was not designed to be used for specific areas. The questionnaire focused on researching the usability of clinical technology environment in which numerous ICT systems are used by physicians. With the questionnaire, we aimed at reaching a wide range of physicians in various areas of specialisation and addressing several usability issues that go beyond traditional approaches: user experience, interaction design, and contextual issues arising from the characteristics of clinical work and physicians' tasks, e.g. appropriate functionality to support physicians in collaborative care. During the questionnaire design the heterogeneity of the target group was seen as a major challenge from the outset. Certainly, the study and the questionnaire had its limitation and were not able to consider all the important and detailed aspects of usability or

consider all the specific characteristics of numerous clinical environments. Nevertheless, the multidisciplinary approach on questionnaire development together with iterative process and close collaboration with physicians were seen as essential to overcome the challenges in conducting a national questionnaire study.

Third, the summative evaluation approach provides general hints to problem areas but is unable to either detect concrete weaknesses or reveal the causes. As pointed out by Kirakovski, usability questionnaires fit together with other usability research methods; however, other methods are needed to overcome the limitations: complement the subjective data, understand the "big picture", and provide answers to *why?* questions [74]. A recent study, conducted by Horsky et al. [80], is one of the few studies which have provided information on the comparison of usability methods and their applicability during healthcare ICT development. Their experiences suggest that a questionnaire provides a direct clinical response with a potentially wide reach, but does not allow for reporting problems in real-time and has a low descriptive value. Our findings on the questionnaire method are congruent with these. Different from others, however, our study incorporated a significantly large amount of responses. When looking for answers to the questions on further ICT development, analysis of open-ended answers and supplementary data gathering using field studies can help us to understand contextual problems and address concrete activities in system redesign.

8. Conclusions and directions for further research

To conclude, our usability results raise several concerns about physicians' daily used tools and waste of operative resources possibly due to failures in ICT development and usability work. The fact that physicians' ratings for EHR systems were rather low indicates the overall dissatisfaction towards clinical ICT systems and their abilities to support routine tasks. The study findings indicated that a significant amount of developmental work needs to be done in order to achieve the benefits of healthcare technology applications since the present systems do not meet their goals in terms of support for the clinical work of physicians.

Based on the described study, several topics for further research can be pointed out.

The reported questionnaire study revealed some results about differences between healthcare organisations and the abilities of the systems to adjust to these. Further analysis should find out if there are significant differences between the responses from various clinical units inside the organisations (e.g. wards and operation rooms). Such results and findings could be used to support the development of the systems, specifically targeted to certain organisations or specialised units, as well as to determine into which environments and context-specific needs the currently used ICT systems fit best.

In this article we argued that the focus of usability studies in health informatics field should be broadened and deepened not only to cover user-interface issues but also the practices and procedures of healthcare work as well as contexts of numerous ICT systems. We believe that the contributions of this article can be considered as a first step towards broadening the scope of usability research in health informatics domain and increasing the understanding of those contextual aspects which are unique in clinical contexts. However, more research is also needed to better understand the contextual aspects of usability in clinical contexts. For example, our experiences suggested that aspects of patient safety and privacy play an import role in clinical contexts. Also, researchers in the health informatics field have argued for legal and safety requirements which have an impact on user interface and system design [6].

The further conceptual analysis around concepts of *usability* and *context* should carefully consider those interests usability and HCI research share with other academic research fields, e.g. with information and communication theory and measurements of information systems success [26]. During our study, it became evident that several items in the questionnaire addressed both usability attributes and information system (IS) success variables. For example, Hyppönen et al. [27] have defined the contextual categories and dimensions of information needed to monitor IS success, building on previous work on activity theoretical framework for evaluating IS success [25] and IS success model [26,28]. Therefore, the work presented in this paper can be considered to parallel work on contextually complex IS success [27,28].

Authors' contribution

All the authors Johanna Viitanen, Hannele Hyppönen, Tinja Lääveri, Jukka Vänskä, Jarmo Reponen and Ilkka Winblad contributed to the study design, data analysis and interpretation, and reporting of the results. Johanna Viitanen is the main author and responsible for the whole content of the article including conception and design, creation of conceptual framework, questionnaire development, data interpretation as well as drafting and revising, and final approval of the article. Hannele Hyppönen is responsible for questionnaire development and statistical analysis, as well as conception and design of the article, revisions, and final approval. Tinja Lääveri is responsible for questionnaire development, interpreting the results, and revising and final approval of the article. Jukka Vänskä is responsible for coordinating the questionnaire project, questionnaire development, statistical analysis, as well as approval of the article. Jarmo Reponen is responsible for questionnaire development, for interpreting the results, revisions and final approval of the article. Ilkka Winblad is responsible for statistical analysis, interpretation of the results, as well as approval of the article.

Conflicts of interest

There are no commercial interests and no conflicting interests in relation to the reported study. The authors have positions as researchers in university, health related research institute and healthcare organisation, or are employed as medical practitioners with healthcare organisations.

Summary points

What was already known on the topic?

- Usability is a contextual property and should always be defined and measured in relation to a specific context of use.
- Usability studies in the health informatics field typically apply traditional evaluation methods, focus on a single system under evaluation and involve a rather small group of end-users.
- Currently used healthcare information systems suffer from a high number of usability flaws.

What did this study add to our knowledge?

- In Finland, physicians' estimates about the usability of their clinical ICT systems, in particular EHR systems, are very critical.
- Results from the national questionnaire study provided a generalized picture about the usability problems. The findings agree with earlier reported results regarding the multiplicity of usability problems and shortcomings in user-oriented ICT development work.
- The article described three usability dimensions which illustrate the characteristics of physicians' work in clinical contexts: (1) compatibility between clinical ICT systems and physician's tasks, (2) ICT support for information exchange, communication and collaboration in clinical work, and (3) interoperability and reliability. However, more research is also needed to better understand the contextual aspects of usability in clinical contexts.

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