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Usability problems do not heal by themselves: National survey on physicians' experiences with EHRs in Finland

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ABSTRACT

Purpose: Survey studies of health information systems use tend to focus on availability of functionalities, adoption and intensity of use. Usability surveys have not been systematically conducted by any healthcare professional groups on a national scale on a repeated basis. This paper presents results from two cross-sectional surveys of physicians' experiences with the usability of currently used EHR systems in Finland. The research questions were: To what extent has the overall situation improved between 2010 and 2014? What differences are there between healthcare sectors?

Methods: In the spring of 2014, a survey was conducted in Finland using a questionnaire that measures usability and respondents' user experiences with electronic health record (EHR) systems. The survey was targeted to physicians who were actively doing clinical work. Twenty-four usability-related statements, that were identical in 2010 and 2014, were analysed from the survey. The respondents were also asked to give an overall rating of the EHR system they used. The study data comprised responses from 3081 physicians from the year 2014 and from 3223 physicians in the year 2010, who were using the nine most commonly used EHR system brands in Finland.

Results: Physicians' assessments of the usability of their EHR system remain as critical as they were in 2010. On a scale from 1 ('fail') to 7 ('excellent') the average of overall ratings of their principally used EHR systems varied from 3.2 to 4.4 in 2014 (and in 2010 from 2.5 to 4.3). The results show some improvements in the following EHR functionalities and characteristics: summary view of patient's health status, prevention of errors associated with medication ordering, patient's medication list as well as support for collaboration and information exchange between the physician and the nurses. Even so, support for cross-organizational collaboration between physicians and for physician-patient collaboration were still considered inadequate. Satisfaction with technical features had not improved in four years. The results show marked differences between the EHR system brands as well as between healthcare sectors (private sector, public hospitals, primary healthcare). Compared to responses from the public sector, physicians working in the private sector were more satisfied with their EHR systems with regards to statements about user interface characteristics and support for routine tasks. Overall, the study findings are similar to our previous study conducted in 2010.

Conclusions: Surveys about the usability of EHR systems are needed to monitor their development at regional and national levels. To our knowledge, this study is the first national eHealth observatory questionnaire that focuses on usability and is used to monitor the long-term development of EHRs. The results do not show notable improvements in physician's ratings for their EHRs between the years 2010 and 2014 in Finland. Instead, the results indicate the existence of serious problems and deficiencies which considerably hinder the efficiency of EHR use and physician's routine work. The survey results call for considerable amount of development work in order to achieve the expected benefits of EHR systems and to avoid technology-induced errors which may endanger patient safety. The findings of repeated surveys can be used to inform healthcare providers, decision makers and politicians about the

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current state of EHR usability and differences between brands as well as for improvements of EHR usability. This survey will be repeated in 2017 and there is a plan to include other healthcare professional groups in future surveys.

1. Introduction

Healthcare IT (information technology) adoption rates are rapidly increasing along with the expected benefits of system usage. In most modern healthcare organisations IT plays an essential role in care delivery and clinicians' daily work. In the Nordic countries the availability and use of local Electronic Health Record (EHR) functionalities has reached a high level (i.e. close to saturation) [1]. In the EU countries access to basic EHRs is by now nearly universal among general practitioners [2]. In the USA the adoption rates of EHR systems in hospitals have increased from 15.6% in 2010 to 75.5% in 2014 [3].

The effects of the adoption and use of EHR systems have not all been positive. Several studies have revealed that usability problems, technology-induced errors and lack of end-user participation in EHR development are continuing issues that need to be addressed (e.g. [4–11]). Poorly designed user interfaces have been recognized to lead to technology-induced errors and thereby may detrimentally affect patient safety [8,12]. Indeed, many technology-associated adverse events in medicine have been attributed to poor interface design rather than human error alone [13].

Clinicians' acceptance of and attitudes towards EHR systems have been shown to relate closely to system usability, for instance ease of use, integration of the systems into clinicians' workflows and helpfulness of the systems in the care of patients [14–16]. In addition, poor system design, system slowdown and system downtime have been considered the most common factors in influencing clinicians' negative attitudes towards clinical IT systems [15]. Usability and human factors approaches need to be integrated into the design and monitoring of EHR system development in order to overcome the prevailing mismatch between clinical work and IT systems and to support practices that improve patient safety. As a result, there are increasing attempts to understand how systems should and could be improved (e.g. [17,18]).

Currently, survey studies of healthcare IT use tend to focus on availability of functionalities (e.g. [19]) along with aspects of technology adoption and acceptance (e.g. [20,21]). The OECD (Organization for Economic Co-operation and Development) has led an effort to provide member states with reliable data in order to compare information and communication technology (ICT) availability and adoption rates in the healthcare sector [22]. Moreover, pre-implementation and post-implementation surveys have been conducted to investigate clinicians' attitudes, satisfaction and reactions towards systems (and their new releases) (e.g. [23]). By contrast, usability and user experience related questionnaires have mainly been applied during IT development processes. The questionnaires have been used for learning about initial use experiences or to compare two or more versions of differing systems (e.g. [14,24–27]) rather than gathering long-term data on experiences about fully adopted systems after longer periods of use.

In the academic literature on human-computer interaction (HCI) and usability engineering (UE) several definitions have been presented for the concepts of usability and user experience (UX). Commonly cited definitions for usability are given by the ISO 9241-11 standard [28] and Jakob Nielsen [29]. These definitions share similar usability components in common – for instance efficiency, satisfaction and effectiveness—and emphasize the role of context. At a more concrete level, usability has been described as follows: "*A system with good usability is easy to use and effective. It is intuitive, forgiving of mistakes and allows one to perform necessary tasks quickly, efficiently and with a minimum of mental effort. Tasks which can be performed by the software (such as data retrieval, organisation, summary, cross-checking, calculating, etc.) are done in the background, improving accuracy and freeing up the user's cognitive resources for other tasks.*" [30]. Moreover, as usability lies in the interaction of the user and the system [31], quality of use has been described as the object of usability. A quality of use model, described by the ISO 25010 standard [32], includes five characteristics: effectiveness, efficiency, satisfaction, freedom from risk and context coverage. The first three of these components are also part of widely known usability definitions [28,29].

In contrast, UX (user experience) as a concept still remains vague despite dozens of attempts to define it [33–35]. Several of these definitions describe UX as a personal experience including aspects of emotions, beliefs and perceptions that occur before, during and after system use [36–38]. These aspects can be also seen as part of the concept of usability as suggested by ISO 9241-210 standard [36]. Usability should be understood as a contextual property. In the field of health informatics this means that aspects of safety and prevention of medical errors as well as characteristics of healthcare work need to be taken into consideration when designing usability studies. Kushniruk et al. [8] have stated that "*the ability of methods from usability engineering to be able to predict medical errors holds considerable potential for assessing healthcare information systems regarding safety and ensuring that such systems do not inadvertently introduce medical errors*".

In our own studies [4,39–41] we have applied definitions of usability from the HCI field when describing the usability of clinical ICT systems from the viewpoint of different end-user groups with the aim of increasing the understanding of contextual aspects unique in clinical contexts. The objective of designing systems for usability can be described as enabling users to achieve goals and meet their needs in a particular context of use [28,36]. Following from this, we have presented a description for usability of clinical ICT systems from the physician's viewpoint [4]: *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. At a more concrete level, this indicates that systems should provide 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 and be interoperable and reliable. Since clinical ICT systems are used in numerous environments, they should also adjust to various user needs and organisational settings.*

The focus of this article is on usability of EHR systems and physicians' experiences in using these systems. Only a few studies have been conducted on a large scale about the usefulness and usability of EHR systems from the end-users' viewpoint over the past few years. National surveys that include usability-related questions have been conducted in some Nordic countries [1,42–44], but the focus of these works has mainly been on adoption and intensity of use. To our knowledge, besides our previous study [4,9,41,45–49], specific national usability surveys have not been systematically conducted among any healthcare professional groups. Longitudi-

nal eHealth observatory studies on usability will become essential when moving from adoption to the next level: monitoring of use, usability and end-user experiences of EHR systems as tools for supporting and renewing work processes and care outcomes as well as the impacts of development activities and updates during established use.

1.1. Context of the study

1.1.1. Healthcare in Finland

Healthcare in Finland consists of a decentralized, three-level public healthcare system and a partly publicly reimbursed private sector. Municipalities are responsible for primary healthcare. Moreover, all of the over 300 municipalities belong to one of the 21 hospital districts, which provide public secondary care, both inpatient and outpatient. Out of these, five university hospitals also provide tertiary care. The vast majority of severely ill patients are treated by the public healthcare system, for instance there are no private intensive care units and all organ transplantations are performed in the public sector. General practitioners in healthcare centres act as gatekeepers to services at secondary and tertiary levels of care, and a referral from a primary care provider is necessary in non-urgent cases. However, the private sector covers as much as one third of outpatient visits [50]. Many of these are occupational healthcare visits. Many Finnish patients choose private providers in order to choose their physician in a secondary/tertiary care setting or to avoid long wait times for primary care physician appointments [51].

1.1.2. Physicians in Finland

In 2014, there were 16,350 working-age (<65 years) physicians living in Finland that were doing clinical work [52,53]. Physicians working in hospitals often work both in outpatient clinics and inpatient wards. The number of physicians has increased by approximately 2000 since 2010. The proportion of physicians in the youngest and oldest age groups as well as female physicians has grown since 2010 [54].

1.1.3. Health information systems and information exchange in Finland

EHR coverage reached 100% in public healthcare in 2010. In addition, the vast majority of private healthcare providers use EHR systems [42,55]. A single administrative register of patient information generated by different public healthcare providers within a hospital district was made possible only by the new healthcare act in 2011. This has increased data sharing between primary and secondary care [42] via joint registers or regional health information systems.

At the time of the survey in the spring 2014, health information systems were undergoing a remarkable reform in terms of connectivity and new functionalities: the e-prescription functionality had already been fully implemented in all public healthcare settings and in two out of three private sector EHR systems that are included in this study. All prescriptions are in one single database that can be accessed by pharmacies, healthcare providers and patients alike. By contrast, the implementation of the national patient data repository (Kanta) had only started in one small hospital district, but some of the EHR systems had already deployed the functionalities needed for integration with the Kanta services.[1]

[1] The National Archive of Health Information (Kanta) is the name of the national data system services for healthcare services, pharmacies and citizens. The services include the electronic prescription, pharmaceutical database, My Kanta pages, and patient data repository. The services are deployed in phases throughout Finland. More information is available at: http://www.kanta.fi/en/kanta-palvelut.

1.2. Aim of the paper

This paper presents a follow-up of a cross-sectional study of physicians' experiences with currently used EHR systems in Finland. The first national study was conducted in 2010 [4,45,46,49]. This study formed the baseline for the follow-up study results to be reported in this article.

The aim of this paper is to present the 2014 survey results on Finnish physicians' experiences with EHR use and compare those with the 2010 results by analysing data from two perspectives:

a) To what extent has the overall situation regarding usability changed?.
b) What differences are there between public hospitals (both outpatient and inpatient), public primary healthcare centres (outpatient) and private providers (mainly outpatient)?.

2. Related research: questionnaire studies on EHR usability

The approach and focus of surveys on EHR adoption and usability seem to differ across countries [56]. For example, Canada is at an earlier stage in EHR adoption and does not have a national questionnaire focused exclusively on questions about EHR use. Questions about IT usage are part of a larger Canadian physician survey, but the current survey does not contain questions about physicians' assessment of the usability of EHRs [56]. The Nordic countries have set up an eHealth group to benchmark the deployment and use of health IT within the five Nordic countries [1]. Albeit the Nordic surveys share several common variables about the usability of the systems, they are not tied to specific functionalities or types of information collected [1]. Usability data has been collected comprehensively with national usability surveys only in Finland and in Iceland [1]. In Finland, the first usability survey for physicians was conducted in 2010 [4] and the Icelandic survey, conducted in 2014, was built based on the Finnish survey [1].

2.1. National usability-focused questionnaire study in Finland in 2010

The national questionnaire study aimed to study physicians' experiences of use, usability and development clinical information and communication (ICT) systems, particularly EHRs, and thereby provide generalized picture about the advantages, problems, and challenges that were related to these systems. For the study a tailored usability-focused questionnaire was designed by a multidisciplinary group or researchers [4]. Usability questions in the questionnaire were derived from the conceptualization for usability of clinical ICT systems (described in [4]). The questions addressed various aspects of clinical ICT system use from a physician's viewpoint:

- Compatibility between systems and physicians' tasks including statements about key functionalities, efficiency of use, intuitiveness of EHR user interface
- System support for information exchange, communication and collaboration in clinical work
- Integration and interoperability between the systems, as well as reliability and technical functionality [4].

In addition, the usability questions reflected various usability aspects, for instance

- *Efficiency* of conducting routine tasks
- Physicians' *abilities to utilize* key functionalities such as summary views

- *Learnability* with respect to the required amount of training
- *Safety or errors* (as in low error rates) of medication ordering processes and serious adverse events for the patient caused by faulty EHR system functions.

Most of the usability questions were formulated as statements. The questionnaire also included a summative question about the overall rating (so called school grade) to the physician's principally used EHR system.

Altogether 3929 physicians actively working in patient care in the public and private sectors responded to the web-based questionnaire in 2010 [4].

Results from the study have been reported in several publications [4,9,41,45–49]. The main usability findings were that physicians' estimates about the usability of their clinical ICT systems indicated that they were critical of their system's usablity [4]. The overall grades given to EHR systems varied significantly: scores for systems used in private sector were higher than for those used in public hospitals and healthcare centres. In general, the physicians indicated that the systems lack a proper patient overview/dashboard and they should better support routine tasks, decision making, prevention of medical errors, cross-organizational information exchange and communication, as well as collaboration between physicians, nurses and patients [4]. The results also showed differences between responses from public hospitals, public healthcare centres and private sector organisations [4,48]. Physicians working in public hospitals and in wards were more critical than their colleagues in other organisations [48].

The questionnaire study for physicians conducted in 2010 can be seen to have an impact on monitoring user experiences on eHealth: the survey tool and results have been exploited within Finland as well as internationally. In Finland, the study results promoted discussions among vendors, ministry, healthcare organisations and research institutes about how to better understand the current challenges and enhance collaborative actions in improving the situation. The study has also impacted the new eHealth strategy in Finland [57]. In Finland there is a continued commitment to monitoring usability and end-user experiences. Such surveys will be continued, and extended from physicians to nursing staff. Many of the Finnish survey variables have been taken as a benchmark in the Nordic eHealth indicator work [58]. Iceland used identical variables to monitor user experiences within different stakeholder groups in 2014. Future work includes establishing a permanent system for gathering, analysis and publication of results of the common benchmarking variables [59].

2.2. Literature review on questionnaire studies on EHR usability

Based on our prior questionnaire study in 2010 (described in Section 2.1) and related review of literature [4], the assumption was that there are not many monitoring studies about EHR use in the health informatics field. To complement our knowledge on, we conducted a literature search to find recently published academic articles on usability surveys published after 2009. Our aim was to find articles reporting wide-scale surveys on clinicians' experiences with usability of EHR systems which we could compare the results of our cross-sectional study with.

Articles were searched following a scoping review approach from PubMed using the keywords: "usability" and "questionnaire" combined with "EHR"; "EPR" (abbr. of electronic patient record); "health information exchange system"; and "national". In addition; search terms "longitudinal + study + usability" were used to specifically search articles reporting usability related longitudinal; cross-sectional; and follow-up studies. The inclusion criteria for articles was the following:

- published between 2010 and 2015, in English
- studies usability of healthcare IT systems in use or recently implemented
- focuses on large health information systems like EHRs (not in a mobile application or a small part of a larger IT system)
- studies usability from the perspective of clinicians' experience on use
- reports an empirical study including data gathering
- reports a study, in which surveys are used as an independent method (e.g. not complementing usability testing).

In total 163 citations were returned. The titles of all the found citations were reviewed. The review was conducted by the first author of this paper. Nine articles met the criteria based on their title and abstract review. Two of these articles reported results from our prior questionnaire study in 2010 in Finland (Refs. [4] and [49]) and were not included in further in-depth review. The summary of the remaining seven articles is presented in Table 1. Two of the articles focused on clinical IT systems (including EHRs) in use [64,69], one on health information exchange (HIE) system [61] and one on an order entry system [70], whereas three studies were on the implementation of EHR systems [60,63,66]. The studies applied various kinds of questionnaires (e.g. Avl [60], IsoMetrics [65]) and themes of questions ranged from graphical layout and adequacy of training to perceived patient outcomes. The number of respondents per study varied from 32 to about 1000.

Based on the review it appears that long-term research and follow-up studies of usability of EHR systems in use are scarce. Only the German study [64] reported results, which can be used to get an overview of the current situation of usability and compare a number of assessed systems. The study covered a wide range of IT systems in hospitals and was targeted to different user groups: clinicians, radiologists and laboratory personnel, as well as administrative, management and IT-employees.

EHR implementation studies [60,63,66] showed that clinicians were satisfied with the EHR in general, but dissatisfied with EHR usability [63]. Factors related to system design had strong effects on acceptance, even one year after implementation [66]. Skilled clinicians may be able to overcome usability obstacles but this requires that they are given the proper resources, education and training [60]. A four-year study of IT supported clinical pathways found that the end-users' estimates of usability were rather satisfactory: on a four point Likert-scale (1 = bad, 2 = acceptable, 3 = good, and 4 = very good) the average was close to 2.5. Based on analysis, the subjective estimates slightly improved two to four years after HIS software implementation, however, no statistical significant differences were found in the time course [69]. In regard to HIE, the findings in a study in USA concerning the user satisfaction on interface design show encouraging results [61]: All the 35 items of QUIS (Questionnaire for User Interaction Satisfaction) had scores over 50%, which were above neutral (a QUIS score of 5 is neutral and a score of >5 favourable) while the mean score was 6.5.

3. Methods

The aim of our national questionnaire study was to explore Finnish physicians' experiences with the use of their current clinical IT systems, particularly EHR systems. The idea was to utilize the usability-focused questionnaire designed for the study in 2010 to gather repeated data and to find out to what extent the overall situation regarding usability has changed and what differences there are between healthcare sectors.

The backbone EHR systems included in this study are based on an architecture where core patient information, narrative patient record texts from medical specialities and administrative hospital

Table 1
Summary of articles.

Authors/Year of publication/Reference number	HIS concerned	Research methods	Themes/questions in the questionnaire	Number of respondents
Janols, Lind, Göransson and Sandblad, 2014 [60]	Deployment of three modules of EPR systems in Sweden	A validated questionnaire Avl was one of the used methods	16 questions on system development, usage, utility, competence, stress and health, relations	Physicians, nurses, clerks (N not reported)
Gadd, Ho, Cala, Blakemore, Chen, Frisse and Johnson, 2011 [61]	HIE system in use in USA	Selected items from a validated instrument Questionnaire for User Interface Satisfaction (QUIS)[62]	Themes: Overall reactions, screen, terminology and system information, learning, system capabilities, system functionality	165 physicians, nurses and others (70% response rate)
Sockolow, Weiner, Bowles, Abbott and Lehmann, 2011 [63]	Recently implemented EHR in USA	Clinician satisfaction survey was one of the used methods in the study	22 questions on impact of the EHR on clinician satisfaction with team communication and perceived patient outcomes	37 + 32 physicians (11 and 17 months post implementation, response rates of 95% and 82%)
Bundschuh, Majeed, Bürkle, Kuhn, Sax, Seggewies, Vosseler and Röhrig, 2011 [64]	Clinical IT systems in German hospitals	Web-based questionnaire, based on IsoMetrics inventory [65]	37 questions on suitability for the task, suitability for the learning, conformity with user expectations, effectiveness	1003 respondents (including 658 clinicians and 73 non-bed-side medical personnel) from 158 hospitals (11% response rate)
Carayon, Cartmill, Blosky, Brown, Hackenberg, Hoonakker, Hundt, Norfolk, Wetterneck and Walker, 2011 [66]	Recently implemented EHR system in intensive care units (ICU) in USA regional medical centre	Survey based on established instruments to measure technology acceptance, EHR usability, and EHR usefulness [62,67,68]	Themes: Overall acceptance of the EHR technology, perceived usability, perceptions of usefulness, information received by the end-users about EHR implementation, participation in implementation activities	121 + 161 nurses (3 and 12 months post implementation, response rates of 51% and 72%)
Schuld, Schäfer, Nickel, Jacob, Schilling and Richter, 2011 [69]	IT-supported clinical pathways in a German hospital (HIS software including e.g. patient data management system)	Annual survey 2006–2009 (interviews and standardized questionnaires) to research staff satisfaction	Themes: comprehensibility, usability and graphical layout (the article does not describe details of the user questionnaire)	Physicians and nurses (N not reported)
Tan, Flores and Tay, 2010 [70]	Order entry system used in hospitals in Singapore	A survey tool designed for the purposes of this study	16 questions on reliability, speed of the systems, ease of use, adequacy of training, impact on productivity, impact on patient care, overall satisfaction	52 physicians and nurses (52% response rate)

Abbreviations:
EHR = Electronic health record.
EPR = Electronic patient record.
HIE = Health information exchange.
HIS=Health information system.

information system information are available in digital format via a common user interface. The same user interface gives access to local medication data, nursing documents and a diagnosis history. Depending on the EHR system, radiology images and laboratory data are stored in a separate database, but usually they are retrieved by exchanging the patient context and seen through the main EHR system. Also the computerized order entries are managed in the main EHR. There are some electronic departmental systems typically in intensive care, operation theatre or emergency rooms which are not integrated to the main system. Virtually all documentation in Finnish healthcare is nowadays electronic [42].

The respondents were asked to give their assessments in relation to the backbone EHR system they had chosen earlier in the questionnaire. The trade names of these systems and their geographical distribution had remained the same between the studies in 2010 and 2014. Also, the basic architecture and user interface concept had remained the same. In public hospitals and in public primary healthcare centres some functions of the EHR system had changed from 2010: they included the addition of a module to connect with the national electronic prescription database. Also, this basic connectivity to the national health information exchange (HIE) has caused modifications to the internal structure of the software: strong user authentication with a national smartcard was taken into use and many codes and classifications were unified. However, full connectivity to the national patient record archive was still ahead as it was planned for the years 2014 and 2015. Among private providers of EHR systems, these changes had not yet taken place at the time of the survey. For software providers, this transition period in connectivity to the national HIE had probably taken a lot of development resources which otherwise could have been used for user interface development.

3.1. Questionnaire

The usability-focused questionnaire included 18 background questions, 38 core statements with a five-point Likert-scale and a question for the overall rating of the EHR-system in use (see Appendix 1 in Supplementary material). In addition, there were other groups of questions addressing issues of management, patient safety, work well-being, information systems development, EHR features that are working well or are considered as the most important development targets. The physicians were instructed to answer questions about the EHR system they primarily use in the context of their daily work. Out of 38 core statements, 24 usability statements which were identical in 2010 and 2014 were selected for analysis in this study. Based on earlier experience with the 2010 responses some questions where rephrased to increase clarity. Since these questions may now carry a different meaning, they have not been taken into account in the analysis.

3.2. Data gathering

The data was gathered from February to March 2014 by using a web-based questionnaire. The individual links to the questionnaire were sent via e-mail to all physicians who were currently living in Finland and who were under the age of 65. The e-mail addresses of the study population were obtained from the register of the Finnish Medical Association, which covers more than 90% of active physician addresses. The researchers were not able to identify individual respondents.

The invitation to the survey was emailed to all working age physicians in Finland. The actual target group, physicians doing clinical work, was highlighted in the e-mail message. Based on the Finnish Medical Association's register, there were 16 350 working-age physicians engaged in clinical work in 2014 [52,54] while the corresponding figure in 2010 was 14 411. The number of respondents was 3781 (23%) in 2014 and 3929 (27%) in 2010. In the 2014 survey some of the respondents were different from those in the 2010 survey (i.e. respondents were at least partially different individuals in each survey).

There was a possibility to choose "other" as a main EHR system if the respondent did not consider any of the ones listed as their primary EHR system. There were dozens of smaller brands with less than 25 respondents each. The responses were anonymized after the respondents had used the link sent by the Finnish Medical Association. In order to make the situation more comparable between 2010 and 2014 the researchers decided to discard the brands with the least number of physician users because we could not track the changes that have occurred in either the user organisations and practices, user groups or the EHR systems themselves between 2010 and 2014.

3.3. Analysis

An analysis was conducted of user responses to the 24 usability-related statements that were identical in the 2010 and 2014 survey. Since the respondents were not identified and in order to make the results more comparable, only the respondents that had replied about using the nine most commonly used EHR system brands were included. This resulted in the exclusion of 706 respondents from 2010 and 700 from 2014 data (see Fig. 1).

The following modifications to the original data were performed:

1) The original scale of overall ratings was from 4 to 10, which follows the typical scale used at Finnish schools (4 meaning 'fail' and 10 meaning 'excellent') and therefore was found intuitive for the Finnish respondents. The scale was changed to be from 1 ('fail') to 7 ('excellent') for the purposes of presenting the results to an international audience.
2) The five-point Likert-scale answers 'Fully agree' and 'Somewhat agree' were combined to form the category 'Agree'. Similarly the answers 'Fully disagree' and 'Somewhat disagree' were combined to form the category 'Disagree'.

For categorical variables the statistical analyses were carried out with Chi-square tests or Fisher's exact test, when applicable. Continuous variables were compared using a one-way analysis of variance. Statistical significance was defined as $P < 0.05$. The statistical analysis was conducted using SPSS 22 software (IBM Corp, Armonk, NY).

4. Results: changes between 2010 and 2014

The results are divided into three sections: respondents' demographics 2010 and 2014 (Table 2), overall ratings for EHR systems (Table 3), and responses to usability statements presented by healthcare sector: public hospitals (both outpatient and inpatient), public primary healthcare centres (outpatient) and private providers (mainly outpatient) (Table 4).

4.1. Respondent demographics

The demographics of the users of the nine most commonly used EHR system brands are described in Table 2 which shows similar demographic features of our subset of physicians with the target population (described in [4] and [53,54]). The proportion of females among respondents had increased between 2010 and 2014. The youngest age group of respondents had also grown in size in both surveys. Corresponding changes could also be seen in the target population. The proportion of different working sectors had remained similar.

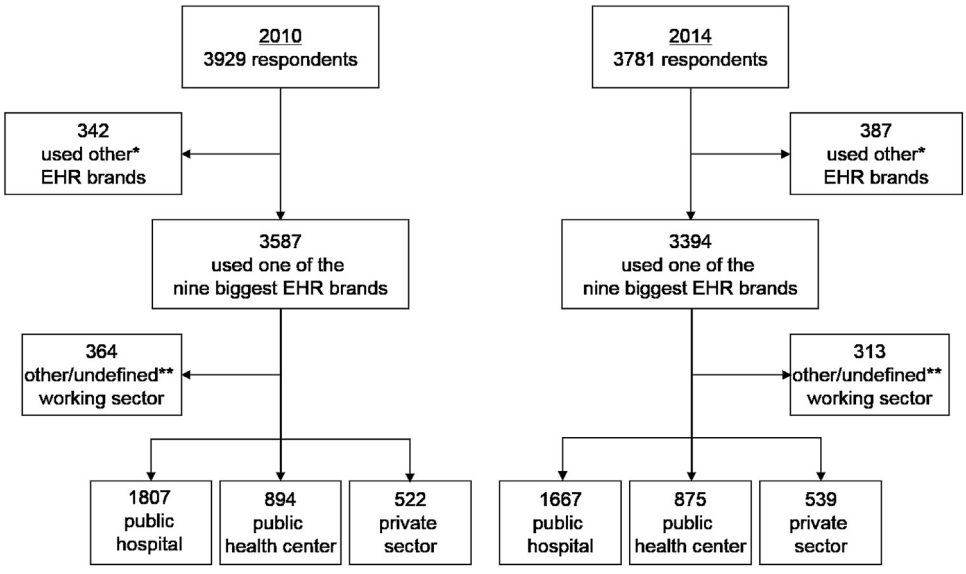

Fig. 1. Selection of data for the analysis.
*EHR brands that were used by less than 25 respondents or the respondents did not define the brand.
** r.g. Government sector or University or undefined.

Table 2
Respondents' demographics in the 2010 and 2014 surveys.

		2010	2014	Physicians in Finland 2014 under 65 years [52]	*p*-value for change between 2010 and 2014
Number of respondents in the whole survey		3929	3781		
Number of respondents in this study		3223	3081		
Number of physicians in Finland under 65 years		18 933	20 110		
		n (% of respondents in the study)	n (% of respondents in the study)	%	
Gender					<0.001
	Female	1840 (57)	1909 (63)	58	
	Men	1370 (43)	1130 (37)	42	
Age					<0.001
	<35 years	454 (14)	633 (21)	21	
	35–45 years	797 (25)	669 (22)	25	
	46–55 years	1156 (36)	841 (28)	29	
	>55 years	785 (25)	873 (29)	25	
Healthcare sector					0.232
	Public hospital	1807 (56)	1667 (54)	53	
	Public healthcare centre	894 (28)	875 (28)	26	
	Private providers	522 (16)	539 (18)	21	

Table 3
Physician's overall ratings with scale from 1 (or 'fail') to 7 (or 'excellent') for their principally used EHR systems (N > 30). In 2014 the physicians had to give an overall rating scale or choose "I do not wish to answer". The proportions of different brands were similar between 2010 and 2014 (p = 0,232).

EHR system	2010			2014			p for difference between 2010 and 2014
	Respondents (total = 3223) N (%)	Respondents having given a score (total = 2041) N (%)	Mean opinion score (scale 1–7) (std. deviation)	Respondents (total = 3081) N (%)	Respondents having given a score (total = 3057) N (%)	Mean opinion score (scale 1–7) (std. deviation)	
Public hospital							
K	218 (7)	148 (7)	**4.2** (1.2)	195 (6)	194 (6)	**4.3** (1.2)	0.341
L_h	75 (2)	51 (2)	**2.5** (1.3)	47 (2)	46 (2)	**4.2** (1.3)	<0.001
M_h	462 (14)	289 (14)	**3.7** (1.1)	432 (14)	428 (14)	**3.5** (1.2)	0.043
N_h	102 (3)	60 (3)	**3.1** (1.2)	107 (3)	106 (3)	**3.4** (1.7)	0.186
O	950 (29)	580 (28)	**3.1** (1.2)	886 (29)	881 (29)	**3.2** (1.2)	0.295
Public healthcare centre							
P	44 (1)	31 (2)	**3.9** (1.4)	37 (1)	37 (1)	**4.4** (1.0)	0.092
L_c	50 (2)	34 (2)	**3.9** (1.5)	71 (2)	71 (2)	**4.0** (1.2)	0.952
M_c	439 (14)	274 (13)	**4.1** (1.1)	424 (14)	419 (14)	**3.6** (1.2)	<0.001
N_c	361 (11)	231 (11)	**3.2** (1.2)	343 (11)	343 (11)	**3.4** (1.1)	0.031
Private providers							
Q	375 (12)2	249 (12)	**4.2** (1.0)	379 (12)	373 (12)	**4.3** (1.1)	0.324
R	87 (3)	60 (3)	**4.3** (1.0)	96 (3)	96 (3)	**4.0** (1.3)	0.097
S	60 (2)	34 (2)	**3.5** (1.1)	64 (2)	63(2)	**3.5** (1.3)	0.937

4.2. Physicians' overall ratings of their EHR systems

Table 3 presents the EHR systems used and their context of use, as well as the mean opinion scores in 2010 and 2014 on a scale from 1 ('fail') to 7 ('excellent'). The average of the ratings varied from 3.2 to 4.4 in 2014 (from 2.5 to 4.3 in 2010). Three of the EHR systems (systems labelled L, M and N) are used both in public hospitals (denoted with a subscript 'h') and in public healthcare centres (denoted with the subscript 'c'). The ratings were rather low in 2010, especially for the hospital EHR systems. In general, the mean opinion scores given in 2014 accord with our earlier study findings. However, some changes are also shown: the average rating had improved for the systems L_h (from 2.5 to 4.2) and N_h (from 3.1 to 3.4), whereas the mean opinion score had decreased for the system M (M_h from 3.7 to 3.5 and M_c from 4.1 to 3.6).

4.3. Responses to usability statements: 2010 compared to 2014

Table 4 presents the summary of the findings for each 24 usability statement. The table shows changes between 2010 and 2014 'agree' responses by healthcare sector. The similar analysis of 'disagree' responses of the same data is available as Supplementary material (Appendix 2 in Supplementary material).

Analysis of 'agree' responses from 2010 and 2014 show notable improvements in the following EHR functionalities and characteristics:

- Help in preventing errors and mistakes associated with medications (all agree (%) from 28 to 41) (statement 1)
- Summary view on patient's health status (all agree (%) from 14 to 24) (statement 2)

Table 4
Summary of questionnaire items (usability statements) and physicians' responses: Changes between 2010 and 2014 for AGREE responses by healthcare sector. The bold numbers represent the "best" response in the two years that are compared and reflect whether the significant change is an improvement or not.

Item no.	Statement	Public hospitals AGREE (% of respondents in working sector) (N = 3474)		p-value (between 2010 and 2014)	Public healthcare centres AGREE (% of respondents in working sector) (N = 1769)		p-value (between 2010 and 2014)	Private sector AGREE (% of respondents in working sector) (N = 1061)		p-value (between 2010 and 2014)	All AGREE (%)		p-value (between 2010 and 2014)	Total nr of responses to statement
		2010	2014		2010	2014		2010	2014		2010	2014		
	Total nr of respondents in year and working sector	1807	1667		894	875		522	539		3223	3081		6304
1	Information systems help in preventing errors and mistakes associated with medications.	19	**38**	<0.001	46	**52**	0.005	30	**34**	0.136	28	**41**	<0.001	6203
2	The EHR system generates a summary view (e.g. on a timeline) that helps to develop an overall picture of the patient's health status.	13	**28**	<0.001	14	**18**	0.137	17	17	0.975	14	**24**	<0.001	3970
3	Information systems help to improve the quality of care.	30	**33**	0.022	38	**40**	0.308	37	**42**	0.120	33	**37**	0.003	6215
4	Routine tasks can be performed in a straight forward manner without the need for extra steps using the system.	**28**	25	0.092	**36**	25	<0.001	**56**	54	0.238	**35**	30	<0.001	6265
5	The system responds quickly to inputs.	**36**	26	<0.001	**47**	34	<0.001	**72**	67	0.065	**45**	36	<0.001	6262
6	The arrangement of fields and functions is logical on computer screen.	36	**42**	0.001	**44**	40	0.173	58	**63**	0.090	42	**45**	0.008	6252
7	The system keeps me clearly informed about what it is doing (for example saving data).	28	**29**	0.558	**44**	34	<0.001	45	**47**	0.451	**35**	34	0.164	6253
8	Terminology on the screen is clear and understandable (for example titles and labels).	**40**	39	0.459	**54**	45	<0.001	**60**	59	0.636	**47**	44	0.012	6254
9	Learning to use the electronic health record system does not require a lot of training.	**38**	37	0.253	**37**	24	<0.001	**61**	50	<0.001	**42**	36	<0.001	6270
10	The information in the nursing record is in easily readable.	**27**	26	0.400	**35**	34	0.431	47	**48**	0.886	**33**	32	0.391	5981
11	The patient's current medication list is presented in a clear format.	22	**40**	<0.001	30	**39**	<0.001	15	**18**	0.435	24	**37**	<0.001	5339

Table 4 (*Continued*)

Item no.	Statement	Public hospitals AGREE (% of respondents in working sector) (N = 3474)		p-value (between 2010 and 2014)	Public healthcare centres AGREE (% of respondents in working sector) (N = 1769)		p-value (between 2010 and 2014)	Private sector AGREE (% of respondents in working sector) (N = 1061)		p-value (between 2010 and 2014)	All AGREE (%)		p-value (between 2010 and 2014)	Total nr of responses to statement
		2010	2014		2010	2014		2010	2014		2010	2014		
12	Information on medications ordered in other organisations is easily available.	5	**9**	<0.001	5	**12**	<0.001	4	**9**	0.002	5	**10**	<0.001	6142
13	Obtaining patient information from another organisation often takes too much time.	**76**	81	<0.001	75	75	0.991	**72**	79	0.005	**75**	79	<0.001	6143
14	Information systems help to ensure continuity of care.	37	**42**	0.002	46	**47**	0.977	46	**54**	0.012	41	**45**	<0.001	6233
15	Information systems support collaboration and information exchange between physicians working in the same organisation.	**67**	63	0.312	**70**	68	0.299	67	**68**	0.785	65	65	0.673	6258
16	Information systems support collaboration and information exchange between physicians working in different organisations.	17	17	0.564	15	**19**	0.010	5	**9**	0.016	14	**16**	0.016	6201
17	Information systems support collaboration and information exchange between the physician and the nurses.	34	**45**	<0.001	57	**60**	0.196	48	48	0.992	43	**50**	<0.001	6203
18	The system monitors and notifies when the orders given to nurses have been completed.	14	**18**	0.010	5	**10**	0.008	3	**7**	0.084	11	**15**	<0.001	3947
19	Information systems support collaboration and information exchange between the physician and the patients.	**12**	9	0.004	9	9	0.889	**21**	20	0.388	**12**	11	0.024	6106
20	Use of the information systems frequently takes my attention away from the patient.	**71**	76	<0.001	**67**	71	0.056	**50**	58	0.008	**66**	71	<0.001	6246
21	The system is stable in terms of technical functionality (does not crash, no downtime).	**46**	41	0.001	**54**	46	<0.001	**73**	72	0.680	**53**	48	<0.001	6283
22	Information entered/documented occasionally disappears from the information system.	34	**28**	<0.001	27	**25**	0.259	27	**21**	0.015	31	**26**	<0.001	6225
23	If I have problems with the system I can easily get help.	45	45	0.913	**52**	45	0.005	**61**	60	0.826	**49**	47	0.139	6246
24	Faulty system function has caused or has nearly caused a serious adverse event for the patient.	43	**42**	0.376	**29**	31	0.211	12	**8**	0.046	34	**33**	0.328	6217

- The format of patient's medication list (all agree (%) from 24 to 37) (statement 11)
- Support for collaboration and information exchange between the physician and the nurses (all agree (%) from 43 to 50) (statement 17).

In contrast, the analysis show notable negative changes in the following EHR functionalities and characteristics:

- Quick response to inputs (all agree (%) from 45 to 36) (statement 5)
- The amount of training required to learn to use the EHR (all agree (%) from 42 to 36) (statement 9).

Overall, the portion of respondents agreeing with the positively formatted usability statements is rather low. The following findings can be pointed out as examples. The EHR systems still lack summary views or dashboards (in all sectors only 17–28% of the respondents agreed with the statement about the EHR generating an appropriate summary view), although in hospital EHR systems the situation had improved (from 13% to 28%). IT systems' ability to support collaboration continue to be rated as poor: Physicians in all sectors were dissatisfied with the support for information exchange between professionals working in different organisations (16% of all agree, statement 16) as well as between the physicians and patients (11% of all agree, statement 19). This findings is strongly supported by the analysis of 'disagree' responses (see Appendix 2 in Supplementary material), which show that the portion of disagree answers has grown in all sectors when compared to year 2010 (in public hospitals from 59% to 63%; in public healthcare centres from 60% to 65%; in private sector from 41% to 50%). Furthermore, all physicians continue sharing their concerns about IT system use taking time away from and disrupting care giving activities. Three out of four physicians in public sector organisations (76% in healthcare centres and 71% in hospitals) and more than half (58%) in the private sector believed that the use of the systems frequently takes their attention away from the patient (statement 20).

The analysis show some differences between responses from different healthcare sectors. Compared to responses from the public sector, physicians working in the private sector were more satisfied with their EHR systems with regards to support for routine tasks (statement 4), responsiveness to inputs (statement 5), intuitiveness of the EHR user interface (statements 6–8), and the required amount of training (statement 9). In contrast, the assessments by physicians working in public healthcare centres towards these aspects had become more critical than in 2010. Only in the private sector, the majority of physicians (72% in 2014) seem to be satisfied with their EHR systems with regards to stability of the systems (statement 21). Public sector users were more even more dissatisfied than in 2010 (physicians in public hospitals 41% and in public healthcare centres 46% in 2014). On the statement of 'faulty functions have caused or nearly caused a serious adverse event for a patient' (statement 24) 8% of physicians in the private sector agreed with the statement whereas the portion of physicians working in public hospitals and in public healthcare centres and agreeing with the statement remain much higher: 42% and 31%.

In general, the analysis of 'agree' responses (presented in Table 4) and 'disagree' responses (presented in Appendix 2 in Supplementary material) show similar patterns. The comparison of the findings, particularly "best" responses per healthcare sector, indicate only some small differences which are marked in Appendix 2 in Supplementary material. Most of these differences support the conclusions made based on analysis of 'agree' responses.

5. Discussion

5.1. The main contributions

In this paper, we report Finnish physicians' experiences with the usability of currently used EHR systems, as well as on the changes in their perceptions between 2010 and 2014. Overall, the results indicate the situation has not improved. Physicians' assessments of their EHR systems still indicate inadequacies: on a scale 1–7 the average of the ratings varied from 3.2 to 4.4. In contrast, there were marked differences between the EHR system brands within each of the user categories (private sector, public hospitals and primary healthcare). Although the situation had not improved considerably in general, two interesting changes in physicians' assessments arose: vendor L_h was given the most negative assessments in 2010, but was among the best in 2014, and the assessments of one of the biggest vendors (vendor M) had deteriorated over a four year period. We speculate that the reasons behind these changes are the following: In 2010 L_h had replaced the previous EHR system only three months prior to the study. This was the brand's first implementation in a hospital environment. The reason behind more positive assessments could have their origins in successful development of the product, unsuccessful initial implementation projects, or both. It is unlikely that initial physician change resistance would have been the only explanation for the critical assessments of 2010. Importantly, most of the users are within one hospital district where healthcare centres and hospitals use the same EHR system and the benefits of sharing data could explain at least part of the increase in user satisfaction. For brand M the situation is more complex. One of the reasons could be that integration with national health and information system services has required major revisions of the EHR systems' functionalities, and this may have disrupted physician workflows. In particular, the e-prescription functionality has evoked more criticism than with other brands (data not shown). At least four changes in the IT environment could explain the lack of improvement in users' opinions about the rest of the EHR brands: Firstly, the national eHealth services (Kanta services) have required major revisions to all of the EHR systems, and these could have caused a halt in all other developments. Secondly, the implementation of these requirements may have not improved the usability of these systems. Thirdly, the expected benefits of the Kanta services (standardization of data and sharing information) had not been realized as yet at the time of our survey; only e-prescription had been widely implemented. Fourthly, other IT solutions that the respondents use in their daily lives have developed during the past four years; the EHR systems seem to lag behind in this development.

Physicians should be able to start getting the work done in the way it is supposed to be done without errors. Therefore, the components of user interfaces that provide information about controls for the user should be immediately understandable. The results show that less than half of all respondents agreed with the statements about intuitiveness of EHR user interfaces. These findings reflect experienced learnability and success of user interface design from the physicians' viewpoint. Albeit the end-users were more experienced in using EHR systems, they experienced an increase in the time required to learn to use the systems. On the other hand, clinical work practices tend to become more dependent on digital processes over the years. At the same time less external guiding information is available outside the information systems.

It is also easy to see the link between intuitiveness and error rate or safety of IT use. The physician has a better chance to avoid technology-induced errors and mistakes when using the EHR system, if the system includes functionality to prevent errors, if the system keeps the user clearly informed about what it is doing, and if the user can easily get help when needed. In particular, the find-

ing that one third of all respondents, and even a higher portion (42%) of respondents from public hospitals, had experienced that a faulty system function has caused or has nearly caused a serious adverse event for the patient indicates that the use of the current EHR systems may pose a serious risk to patient safety.

EHR systems should be efficient to use, so that a high level of productivity in a hectic and critical environment is possible. The survey results indicate that with the current EHR systems physicians are not able to conduct their work in an efficient way. This is particularly shown by statements about the availability of key functionalities and the statement about performance of routine tasks. With regards to physicians' responses to these statements, two out of three physicians share this concern: the systems lack those properties that are needed to perform key clinical caring tasks with patients and the systems force the physicians to perform additional tasks or adapt new inappropriate work processes.

From the usability viewpoint it can be argued that efficiency of work is also hindered because of poor IT support for information exchange, communication and collaboration. EHR and related IT systems should serve a single physician but also their work with numerous other parties since clinical processes are characterized with a high degree of communication and cooperation. The results point out particularly the following areas of improvement: availability of information about medications prescribed at another organisation, support for cross-organizational collaboration between physicians, monitoring of orders given to nurses, and support for physician-patient collaboration. Less than 20% of all respondents agreed with these four positively formatted statements. It appears that after its first years of deployment, the national e-prescription database has not as yet ameliorated the availability of medication information across organisations. The study findings provide the baseline status for the national information exchange in Finland. It will be interesting to see how physician experiences will evolve in the post-implementation situation of 2017. Based on results, IT systems' support for collaboration and information exchange between the physicians and patients had not improved; apparently few solutions have emerged to support patient-centred care and patient abilities to participate in their own care. Therefore, based on the results of another national survey, the usage rates for the patient portal functionalities were still very modest [71], and information exchange between patients and physicians was only available in a few organisations [42].

Satisfaction with technical features has not improved in four years. We regard the availability of the EHR systems as one of the central features when the physicians assess the use of these systems. However, the proportion of physicians agreeing with the statement concerning the disappearance of documented data from the system (statement 22) had slightly diminished in all working environments. As we are not aware of major technical failures in data storage in the EHR systems included in this study, we interpret "disappearing data" as an indicator of the most severe usability problems. These include for example (a) the user does not know where to find the information needed, (b) the user has documented it in incorrect fields or modules of the EHR system or, (c) most importantly, at the final stages of documentation process, the user does not notice that he/she needs to press another button in order to actually save the information. Users tend to find ways to move around the usability problems over time [72,73] so well that the developers and trainers may not see them as usability problems at all and blame the end-users for not having attended enough training sessions.

The results also show some differences between healthcare sectors. EHR systems used in the private sector appeared more stable and responded more quickly to inputs as well as providing better support for physicians' routine tasks. The patients in the private sector are less severely ill and seem to have fewer comorbidities; accordingly the lack of dashboards or patient overviews is less likely to interfere with routine tasks. The responses from primary healthcare indicated negative changes in these aspects as compared to the year 2010. One of the reasons behind this could be the increased documentation needs for national reporting (other augmented documentation needs are more local). The results also indicate that physicians working in the public sector (hospitals and healthcare centres) were rather satisfied with their IT system abilities to support prevention of errors related to medication. Healthcare centre EHR system brands had implemented medication interaction alerts already by 2010 whereas this functionality was introduced to the largest brand used in hospitals only after our previous survey, and was still lacking in the private sector.

The analysis of 'disagree' responses show highly similar patterns with the analysis of 'agree' responses and thereby supported the conclusions made based on Table 4. However, the comparison of the findings point out some differences (which are all shown in Appendix 2 in Supplementary material). Probably the most notable differences are related to the statement about system informing the user about what it is currently performing (statement 7), the statement about the arrangement of fields and functions on computer screen (statement 6) and the statement about information system support for physician-patient collaboration (statement 19). In public hospitals and in private sector the portion of physicians disagreeing with the statement no. 7 has grown (in hospitals from 50% to 54% and in private sector from 30% to 36%) even though the analysis of 'agree' responses show that the physicians in both these sectors have given more positive estimates than in year 2010. On the statement no. 6 the analysis of 'agree' responses suggest that the portion of all physicians agreeing with the statement has grown (from 39% to 42%). Interestingly, the portion of disagreeing has also grown from 42% to 45%. Based on our experience, an additional analysis can be particularly useful regarding those statements and results which show only little or no change at all between responses from different years.

One of the central findings of this study concurs with the findings from earlier usability studies [60,72]: Time does not heal usability problems even though time allows users to learn strategies for overcoming some of the problems. Kjeldskov et al. [72] conducted laboratory-based usability testing with an aim to compare the usability of the system as experienced by novice and expert users. The expert users were not more efficient on complex tasks and a remarkable number of serious and critical problems with the system still remained after one year of extensive use. Janols [60] reports similar findings: Even after two years of deployment, the system was not considered to be as supportive as the old system. In addition, clinicians often found ways to overcome problems with system usage; however, these work-arounds typically generated new problems. In conclusion: poor design remains poor even though time allows people to learn strategies to overcoming a system's specific peculiarities.

Earlier studies have also shown that different user groups (e.g. physicians and nurses) have different job roles and responsibilities leading to different needs and expectations of the clinical systems [70]. Similarly, physicians working in different sectors have different needs and requirements for their systems. Specialized information systems with defined functionalities have been reported to receive more favourable assessments than clinical information systems in general [64]. The finding can be attributed to the improved customization of the specialized systems for specific working environments [64]. It is noteworthy that our survey did not cover IT systems used typically in intensive care units or operating theatres, and, accordingly, more international studies are needed to reassess the current situation in these working contexts.

5.2. Relevance of the research

From the academic literature we found only a few examples of usability surveys which have been used to research the usability of EHR systems in use over time in real settings. Approaches to researching adoption and usability of healthcare IT systems vary between countries [56], however, to the best of our knowledge the studies conducted in Finland in 2010 and 2014 are the only cross-sectional questionnaire studies focused on usability and aimed to monitor and follow-up the development of EHR systems at a national level. Reliable academic surveys are needed to study the usability and user experiences of currently used EHR systems and to monitor their development at regional and national levels. Results of implementation and deployment studies suggest that EHR functionality and usability impact clinician satisfaction, efficiency, and clinical use of the EHR. Therefore, one of our aims was to inform decision makers, healthcare organisations and politicians about the usability of currently used EHR systems and improvements that have occurred during the past few years. As suggested by Bundschuh et al. [64], results from national usability studies can be used as reference data for evaluation and benchmarking of user-oriented software engineering for clinical IT, which is relevant for the development and marketing of these systems, as well as for clinical practice and care quality. Furthermore, Carayon et al. [66] have stated that "*it is important for healthcare organisations to continue their efforts to optimize the design and use of EHR after the technology is implemented, since the characteristics of EHR technology, particularly usability and usefulness, have a significant impact on acceptance and use of the technology*". They also suggest that more research using a long-term design is needed to further understand how EHR-related predictors of technology acceptance, including usability, may change over time.

5.3. History of our usability-focused questionnaire

Designing a usability questionnaire study for physicians is challenging. It requires in-depth knowledge about usability research issues and about domain specific characteristics of physicians' context of work. Compared to standardized usability questionnaires (such as SUMI [74], SUS [75] or QUIS [62]), the strength of our questionnaire is that it is focused and specialized around physicians' work and their use of EHR systems. As has been stated in our earlier article [4], the reasons for not using these standardized usability questionnaires were that they focus on a single system of software, evaluate the usability of a user interface, and are context and domain independent. However, we utilised those questionnaires when the original questionnaire was designed and also when we updated the form before data gathering in 2014.

Questionnaire items need to be carefully formulated so that they are correct and appropriate from the respondent's point of view. It is important for the questionnaire tool to address issues it is supposed to address and to be specialized for the context of its intended use. For example, Tan et al. [70] found that in their study physicians had a different concept of user satisfaction as compared to nurses and the data collection tool with its concepts was more effective in measuring nursing constructions than a physician's mindset. Therefore, the questionnaire needs to be carefully pilot-tested with potential respondents. After our study, we found that some specialist groups such as radiologists and laboratory physicians did not find all statements relevant to their everyday work. Only EHR system brands that were used as "foundation systems" were available for selection, therefore, physicians working in intensive care units or operating theatres could not reply based on the speciality IT system brand they used. Most physicians use several other IT systems that store patient information (such as radiology information systems, laboratory information systems) daily. The respondents were not asked to assess the development of EHR systems with regards to the situation four years earlier.

The design of our national usability-focused questionnaire started in 2009 and has had several iterations since. The original version of it was designed by a multidisciplinary group, whose seven members were experts in the areas of usability research, medical informatics, sociology of technology, medicine and medical practices, and occupational health research [4]. The theoretical background of the questionnaire development work originated from a review of the usability literature, particularly from widely known definitions of usability and an analysis of context of use characteristics [4]. Before the first data gathering in the year 2010 the questionnaire had two pilot test phases [4]. After that, the questionnaire was modified based on our experiences from data gathering, analysis and academic discussions. As described in earlier, some statements were modified and added for example to reflect developments at the national level. This kind of iteration and update needs to take place in the future as well. Furthermore, it is important to pilot test the questionnaire every time before it is used with sufficient number of potential respondents. Although the modified questionnaire used in 2014 was tested beforehand, it is likely that physicians from different working environments may understand the statements differently. On the other hand, user experience is context-related and respondents assess the statements based their own experiences.

Even though our questionnaire has such history, one could question the validity and the reliability of the method and the results. To our best knowledge, our survey with Finnish physicians is the first national eHealth observatory questionnaire focused on usability and used to monitor the long-term development. Therefore, we find the method and the results are novel, valuable and of high importance. In addition, the results have practical relevance and they have been exploited within Finland as well as internationally. Our plan is to keep up monitoring the level of usability of clinical IT systems as well as to continue the questionnaire development work. At the same time, we call for collaboration with other researchers and communities around this work to develop validated and reliable academic monitoring surveys for healthcare IT field.

5.4. Strengths and weaknesses of the study

The use of questionnaires is a valuable method for gathering subjective experiences – direct clinical response – with IT usage. Compared with other more qualitative usability methods (e.g. usability testing, expert evaluation, observations or interviews) use of questionnaires is a suitable technique for gathering information from a large target group of end-users. A web-based format makes it easy to reach a high number of desired respondents and inquire about numerous IT-use related themes. For these reasons, a web-based questionnaire was found suitable to be used in our study, which aimed at researching and monitoring the overall level of achieved usability of EHR systems and impacts of development activities at a national level within recent years.

The study suffered from generic limitations typical of studies conducted with the internet survey method [76]: The Finnish Medical Association register did not have email addresses of all physicians. The invitation emails may not necessarily reach the respondents because of firewall settings or other technical issues. Therefore, we can't be sure how many physicians actually got the invitation. Those that were reached might not have answered online surveys. Surveys with closed-ended questions may have a lower validity rate than other question types. Data errors due to question non-responses may exist. The number of respondents who choose to respond to a survey question may be different from those who chose not to respond, thus creating bias. Survey question answer options could lead to unclear data because certain answer

options may be interpreted differently by respondents. For example, the answer option "somewhat agree" may represent different things to different subjects, and have its own meaning to each individual respondent. 'Yes' or 'no' answer options can also be problematic. Respondents may answer "no" if the option "only once" is not available. In addition, issues of anonymous questionnaire method are relevant to point out. In our study, we find assurance of respondent anonymity a key issue. We think this has influenced the response rate in a positive way. Multiple responses from a single respondent were not possible since personalized links were send to respondents. When using anonymous questionnaire it is, however, not possible to evaluate the causality.

When estimated as changes in percentages of physicians agreeing or disagreeing with a statement, our results do not show notable improvements regarding the usability of EHR systems. However, as the number of respondents was high, the statistical method used (Chi Square test) may overestimate the differences between the findings of 2010 and 2014. When considering the relevance of the differences between the findings, it is recommended to pay attention to both the *p*-values and the significance of the change expressed as percentage values.

It is unlikely that the change in respondent demographics would explain the lack of improvements in the opinions of physicians: The proportion of women had increased among both respondents and physicians in Finland between 2010 and 2014. Women had given higher opinion scores than men in both surveys [45,53]. Respondents were younger in 2014 than in 2010, but the opinions scores of the youngest age group had slightly risen between 2010 and 2014 (data not shown). The proportions of working sectors and different EHR systems had remained similar. Since the respondents were not identified, some of the respondents, at least the ones that had finished their studies or retired after 2010, were not the same in 2010 and 2014. However, it is unlikely that physicians who feel less positively about their EHR systems would have responded to this survey, but not the previous one. Of the largest user groups, only one hospital district had changed its EHR system brand between 2010 and 2014, many of the respondents in this survey are likely to have four years more experience in the use of the systems than in the previous one.

The findings on the current state of usability of EHR and related clinical IT systems have novel value, since the applied research approach was not typical of health information studies. The literature review of related studies suggests that a usability-focused national questionnaire with nearly 4000 respondents can be considered exceptional as compared to other similar studies in the field. However, our scoping review had some limitations as well. The review was focused on the academic literature published in PubMed between 2010 and 2015. We are aware that some studies on the topic "questionnaire studies on EHR usability" have been reported before, for instance the academic studies by Christensen et al. [77] and Edwards et al. [78] as well as some comprehensive reviews on EHR systems in the USA market (e.g. surveys by American EHR [79–81]). These non-academic surveys about user satisfaction with EHRs in the USA have been conducted for some years. Conclusions based on these studies, however, seem to be somewhat contradictory and manifold: HIMMS13 reported EHR satisfaction diminishing [82], whereas recently published survey report by AmericanEHR Partners indicate a growing overall satisfaction among physicians with their EHR systems [81]. Interestingly, the report also points out how usability ratings vary between specific tasks (e.g. refilling a prescription was rated as easy whereas importation of a patient's medication list difficult) and between specialities (primary care physicians giving more positive evaluations than other specialists) [81]. What is more, the use of other search terms (e.g. cross-sectional or user satisfaction) could have resulted in more related articles. However, for the key terms we selected "usability" since our general finding is that the terms satisfaction, usability, user experience, usefulness and meaningful use are used in health informatics literature with somewhat contradictory meanings.

5.5. Further research

This article is the first international publication which reports results from our national survey data gathered in 2014. Results from the 2010 survey were reported in several articles [4,9,47–49]. Likewise, in future studies we will analyse the questionnaire data from other perspectives, for instance health information exchange. In addition, our aim is to research for intervening variables to find for example if more experienced IT users may become more critical of the EHR systems they use for work.

Our aim is to continue the monitoring of development of healthcare IT systems in Finland as series of cross-sectional studies on physicians' experiences of EHR system use and usability. This also means that the survey questionnaire needs to be updated to reflect the changes in the field (e.g. regional and national regulations). Updates to eHealth strategy and policy goals (e.g. patient empowerment via patient portal functionalities) call for updates of the survey instrument. The next national data gathering with physicians is planned to take place in 2017. A lot of expectations are associated with the forthcoming more general HIE and user experiences might show different results after Kanta (the national archive of health information in Finland) installations are in full service. The study results can be used to inform healthcare providers, decision makers and politicians about the current state of EHR usability and differences between brands as well as improvements of EHR usability at a national level.

Our current survey did not cover other health professional groups such as nurses. As the EHR is a multidisciplinary platform that is expected to support teamwork, other professionals might be included in future questionnaires (e.g. physiotherapists and various speciality professionals use a common EHR). Medical secretaries perform important tasks in information logistics and scheduling. However, the survey questionnaire needs to be modified for use with the other professions, since the work tasks and responsibilities of other professions differ from those of physicians.

Our national questionnaire study has gained interest in several countries, including Canada and Nordic countries. There is ongoing research activity between Finland and Canada to develop a generalized usability-focused questionnaire for various groups of healthcare professionals, including nurses, based on the Finnish national questionnaire for physicians. It would be interesting to be able to compare the results from national usability studies across more countries and monitor the development of healthcare IT systems at an international level. From a conceptual perspective, our study suggests that more research is needed to understand the relationship between concepts of usability, technology-induced error and patient safety.

6. Conclusion

The healthcare field is continuously changing. Political, organizational and technological changes as well as increasing digitalization have effects on healthcare IT system development and implementation. Research on experienced usability with EHR systems is essential to find out how these changes appear in clinicians' daily work in clinical environments. Based on our best knowledge, the reported cross-sectional survey with physicians in Finland is the first national eHealth observatory questionnaire focused on usability and used to monitor long-term development in this area.

Summary points
What was already known on the topic?

- Questionnaire studies of healthcare IT use typically focus on availability of functionalities, adoption and acceptance aspects.
- Usability is a key factor affecting user acceptance as well as meaningful and safe use of healthcare IT systems.

What this study added to our knowledge?

- The Finnish survey for physicians is the first national eHealth observatory questionnaire focused on usability and used to monitor long-term development in this area.
- Usability of EHR systems in Finland has not improved within four years (2010–2014).
- From the physicians' viewpoint the main usability concerns are related to efficiency of EHR use including lack of support for collaboration and communication, and intuitiveness of user interfaces.
- Surveys about the usability and user experiences of healthcare IT systems are needed to monitor long-term development and guide the development at regional and national levels.

Our results suggests the existence of serious problems and deficiencies which considerably hinder the efficiency of EHR use. Contrary to general expectations, the results do not indicate notable improvements between the years of 2010 and 2014 regarding usability of the nine biggest EHR brands in Finland. Physicians' ratings for their EHR systems remain rather low, which indicates overall dissatisfaction towards the currently used systems and their abilities to support routine work. Compared to the 2010 study, the results show improvements in some functionalities, e.g. prevention of errors associated with medication, summary view of patient's health status and patient's medication list. On the other hand, some changes during the four year period have led to lower usability ratings concerning e.g. ease of conducting routine tasks, quick response to inputs, and the amount of training required to learn to use the system. Physicians working in different healthcare sectors (public hospitals, public healthcare centres and private sector) seem to share their opinion on improvements and inadequacies even though the analysis show some differences between responses from the sectors.

The survey results call for continuous monitoring of EHR development from the end-users' perspective as well as the need for a considerable amount of development work in order to achieve the expected benefits of EHR systems and to avoid technology-induced errors which may endanger patient safety. When developing health information systems for the sake of better healthcare quality (including implementing national strategies as well as national data system services and improving information exchange and connectivity in a regional and a national levels), the clinicians' viewpoint as EHR end-users should not be forgotten or underestimated. The success of the implementation is often dependent on how the change appears in physicians' and nurses' daily work with EHR systems.

Conflicts of interest

No reported conflicts of interest.

Author's contribution

Authors Johanna Kaipio, Tinja Lääveri, Hannele Hyppönen, Suvi Vainiomäki, Jarmo Reponen and Jukka Vänskä contributed to the study design, questionnaire development, data interpretation as well as revisions and approval of the manuscript. D.Sc. Johanna Kaipio had the main responsibility for the manuscript and she conducted the literature search reported in Section 2. Tinja Lääveri (MD), had main responsibility for the statistical analysis. She also contributed actively in all parts of the manuscript. Hannele Hyppönen (PhD), Suvi Vainiomäki (MD), and Jarmo Reponen (MD, PhD) contributed in the Sections 3 and 5. Authors Andre Kushniruk (PhD) and Elizabeth Borycki (MN, PhD) contributed to the conception and design of the article as well as revisions, proof reading and final approval. Together with Johanna Kaipio they were responsible for translating the national questionnaire from Finnish to English. Jukka Vänskä (M.Soc.Sci) was responsible for coordinating the survey project and he contributed to the statistical analysis.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ijmedinf.2016.10.010.

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