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Conference Paper · March 2014

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User-Centered and Persuasive Design of a Web-Based Registration and Monitoring System for Healthcare-Associated Infections in Nursing Homes

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Abstract— Patient safety is increasingly threatened by healthcare-associated infections. To cope with this threat, insight into the occurrence of such infections is paramount. We used a holistic approach for the user-centered and persuasive development of a system for the registration of healthcare-associated infections in nursing homes. To do so, we combined multiple methods (literature search, expert discussion, questionnaire, interviews and scenario-based user-tests), closely cooperating with end-users. This study shows why involving end-users in all stages of development is of paramount importance for the creation of successful eHealth technologies.

Keywords—User-centered design; Persuasive design; Web-based; eHealth technology

I. INTRODUCTION

Healthcare is increasingly confronted with threats caused by Healthcare-Associated Infections (HAIs) [1]. To be able to adequately protect patients from this threat, one of the first steps is to gather knowledge on its occurrence [1]. For hospitals, already a vast amount of surveillance data is available [1-7]. For other healthcare institutions (such as nursing homes), prevalence studies have more recently begun to take place. The results of the first prevalence study of HAIs in Dutch nursing homes were published in 2011 [8].

To enable prevalence research in nursing homes, data must be collected on all clients that are present in the nursing homes at one point in time. The success of such data collection is entirely dependent on the willingness and capability of the elderly care physicians to register their clients in a correct and timely manner. Preferably, the registered data should be collected in a standardized way to fit other (e.g., nation-wide) surveillance programs [1]. One way to achieve this is via the use of a standardized registration system, that allows users to collect, process, and analyze surveillance data.

We developed a registration system to optimally support elderly care physicians in the correct and timely registration of their clients, taking into account the national prevalence studies [2] with which collected data should be compatible. We aimed to do so, by applying user-centered and persuasive design to the development process.

The research question is: How can user-centered and persuasive design improve the registration of HAIs in nursing homes by elderly care physicians? Aim is to make the new registration system reliable, fitting within work processes, and faster, easier and clearer than the current registration method.

First, the methods that are applied in this study are described: the analysis of the current situation via expert discussion (section II.A.); the analysis of the users' needs via a questionnaire study (section II.B); and the analysis of the user-friendliness and persuasiveness via in-depth interviews and scenario-based tests with end-users (section II.C.). Then, the results of the different study methods are given: a description of the current situation (section III.A.); the users' needs and values (section III.B.); the use of persuasive systems design in the prototype (section III.C.); and the user-friendliness of the prototype (section III.D.). Finally, the performed study is discussed (section IV) and conclusions are drawn (section V).

II. METHODS

The Center for eHealth Research and Disease Management (CeHRes) has developed a roadmap (see Fig. 1) that is used as a framework for the holistic development of eHealth technologies [9]. It incorporates principles from business modelling, human-centred design and persuasive design within five development cycles [10, 11].

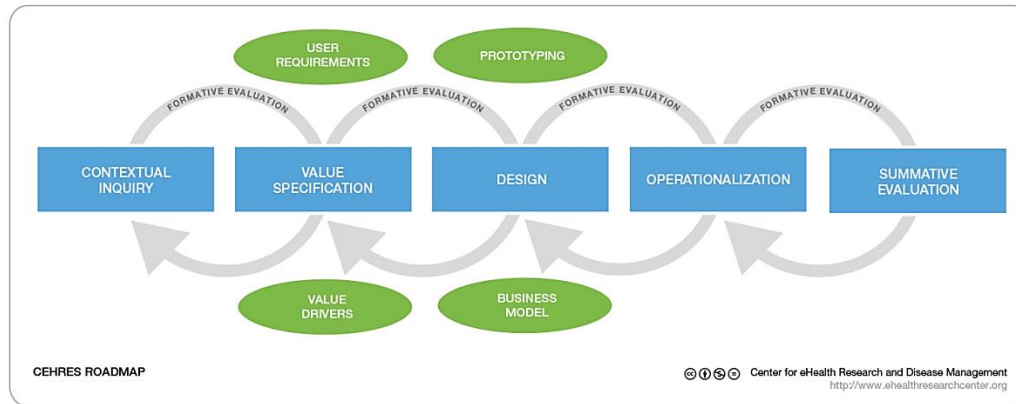


Figure 1. CeHRes Roadmap [9].

A. Analysis of Current Situation via Expert Discussion

This project started with a request from iPrevent [12] to aid in the development of a new ‘mobile’ registration system. iPrevent is a regional infection control network within which healthcare institutions, elderly care physicians, medical microbiologists and Infection Control Professionals (ICPs) work together to structurally offer high quality care in the field of infection prevention [12].

To gain insight into what iPrevent specifically wants or needs from this project, and into the prerequisites for the registration system, an expert discussion was held, with two project leaders (one of whom is also the data analyst) and two behavioral researchers. The outcomes of the discussion were complemented with literature on the registered HAIs and national surveillance.

B. Analysis of Users’ Needs via Questionnaire

Based on the expert discussion a questionnaire was developed, to gain insight in what values end-users had (concerning a registration system) and whether the project aims match these values.

A total of 24 physicians who worked at different nursing homes within the iPrevent network participated in the study. Their age ranged from 30 to 61 (mean age 47 years). Most participants were female (19 female vs. 5 male).

Questionnaire results are analyzed to obtain descriptive statistics. Statistical analyses were deemed redundant, given the developmental purpose of the study. Answers that are given to open-ended questions, were summarized if they overlapped and then their frequencies were analyzed.

C. Analysis of User-Friendliness and Persuasiveness via In-Depth Interviews and Scenario-Based Tests with End-Users

To validate the questionnaire data and to optimize the user-friendliness and persuasiveness of the prototype, scenario-based user-tests and in-depth interviews with end-users are performed.

Four female elderly care physicians who worked in different nursing homes within the iPrevent network participated. Their ages varied from 33 to 59 (mean age 45 years). One of the nursing homes they worked at, already used Electronic Client Files, the others will start to do so in the near future.

Based on the analysis of the context and of the users’ needs, and in close cooperation with an ICP, a prototype of the registration system was developed using Balsamiq software. The prototype incorporated elements of Persuasive Systems Design (PSD) [13]. Not all elements of PSD were deemed relevant for this system, but as much elements as possible have been applied.

Two scenarios were developed for the user tests. They were developed by an ICP and made use of literature on the HAI definitions. The scenarios addressed critical issues for registration.

The physician was instructed to talk out loud during the entire user-test, not only mentioning what she thought, but also what she saw or sought, did or wanted to do.

The entire conversations (including both interview and user tests) took about 45-60 minutes each. Audio recordings of the conversations were transcribed verbatim and analyzed using a code book. Some examples of the codes are given in Table 1. All codes were combined and the frequencies with which they were mentioned were analyzed.

TABLE 1. EXAMPLES OF CODES USED FOR ANALYSIS OF USER-TESTS

Examples of codes used for data-analysis		
Category	Code	Description
Contextual Inquiry	C1	Subject describes a problem that is experienced in the current work process
Value Specification	V1	Subject thinks working with the new system might be faster
Design	D1	Subject thinks the order of the items in the mock up is wrong
Operationalization	O1	Subjects talks about a possible barrier for using the new system

III. RESULTS

A. Current Situation

iPrevent has over the last years worked together with the approximately 30 nursing homes within their network, to perform annual prevalence measurements for nursing home infections. This means that elderly care physicians are required to once a year register all relevant data about the residents that live in their nursing homes. Inherent to the fact that it is a prevalence measurement, all clients must be registered within a short timeframe around a reference date.

The content of the registered data is largely determined by the definitions of HAIs. These definitions were developed by the regional network in cooperation with the national surveillance system (PREZIES) [14]. In the hospital setting, surveillance is performed by trained infection control nurses. The use of the definitions in the nursing home setting, where registration is performed by physicians with little or no experience with surveillance, registration is far more complicated. The currently used registration system translated definitions into questions, but did not offer the physicians any additional support. The prior registration system used a SurveyMonkey questionnaire for registration. The questionnaire consisted of a long list of complicated questions. Many of them are irrelevant for most residents. For example, if a client does not use an antibiotic, the question about what an antibiotic is used for, is rather redundant. Also, all questions are presented on a single page. Physicians thus have to scroll down seemingly endlessly, past irrelevant questions, while scanning to find questions that are relevant, all the way down to the bottom of the page, before they can start with the registration of the next resident.

Furthermore, an increasing amount (>30) of nursing homes participate in the prevalence measurements that iPrevent performs. Thus, increasingly large datasets are collected. Data processing, data analysis and presentation of feedback of the results to the nursing homes are all performed by a single data-analyst. This will soon no longer be feasible. Project leaders (and the data-analyst) therefore would like the system to perform these tasks automatically.

Finally, project leaders requested that the new system would be 'mobile' (to be used on a smartphone) to enable bedside registration of clients by elderly care physicians.

B. Users' Needs and Values

The questionnaire resulted in insight in the context of the problem and in the users' values. When asked what kind of device they would like to use for the registration, most subjects indicated they preferred a PC (50,0%) or laptop (20,8%). The other subjects preferred to use a smartphone (12,5%), tablet (8,3%), or paper (8,3%).

Most important reasons for users to be willing to use the new registration system were: (1) if they can interrupt registration without losing data; (2) if the new system is more user friendly; (3) if it can be opened simultaneously

with Electronic Client Files ('Elektronisch Cliënten Dossier' in Dutch); (4) if clear insight is given in the results; and (5) if registration can be performed faster.

One of the prerequisites that were found during the expert discussion said that it would be desirable if registration could be performed at the residents' bedside. This would enable the physicians to directly see how the resident is doing. However, the questionnaire showed that none of the physicians considered this to be desirable. Most of them (54,2%) did indicate that it would be of added value for them to be more flexible in the location in which they register their clients, but didn't want to do so bedside. Also, 41,7% said that it would not be of added value at all since they just liked to register their residents in their offices. One physician (4,2%) wanted to register her clients in the department's office, with the client files at hand.

Yet, the in-depth interviews gave even more insight into the situation. Physicians explained that their nursing homes were (going to be) using Electronic Client Files (ECF). This is software that contains highly personal and private information about the residents. Therefore, many safety measures have been taken to protect this information. Because of one of these safety measures it is impossible to simultaneously open the ECF and the World Wide Web. In practice, this meant that elderly care physicians had to open the ECF, and write down all the information about all of their clients that they needed to register in the prevalence measurements. Then they had to close the ECF and open the SurveyMonkey questionnaire and enter the information they had written down. Not to mention that if they had forgotten any information, the entire procedure had to be repeated. The subjects therefore did want registration to be possible on a mobile device, but for reasons that differed from what was expected, i.e.: so they could simultaneously open the ECF on their pc and the registration system on the other device.

C. Use of Persuasive Systems Design in the Prototype

1) Primary Task Support

One of the main concerns with working with the prior registration system was that working with the SurveyMonkey questionnaire required the physician to read through many irrelevant questions for every client. One of the most important elements of PSD that were to be used in the new system was therefore *tunneling* [13]. The prototype system was designed to guide the user through the system, questions to be answered are dependent on the answers given to prior questions. Thus, the entire system is a big decision tree, to make sure every client is registered via the shortest (fastest) possible route.

Another concern with the prior registration system was the complexity of the used questions (which were based on definitions of HAI). To reduce the complexity, and thus the risk of interpretation errors, *reduction* was used. The aim of reduction is to reduce complex behavior into simple tasks, to help users perform the target behavior [13]. This was

done by translating complex and long questions into a flowchart consisting of multiple questions. For example, the originally used question for Gastro-Enteritis, was rather lengthy and complicated (see Quote 1).

Does the resident have Gastro-Enteritis? The diagnosis Gastro-Enteritis is given if one of the following symptoms occurs in the client:

- Three times or more diarrhea (different from normal for this client, frequency is not applicable when using incontinence materials)
- Diarrhea and two of the following symptoms: fever, vomiting, nausea, stomach ache, stomach cramps, blood or mucus in feces.
- Vomiting three times within 24 hours, without any additional symptoms (if vomiting is not associated with medicine use)
- Vomiting and two of the following symptoms: fever, nausea, stomach ache, stomach cramps, blood or mucus in feces.

Quote 1. Question about Gastro-Enteritis in the prior registration system (Originally in Dutch)

This question was translated into shorter and simpler questions divided into several screens. Some of these screens are shown in Fig. 2.

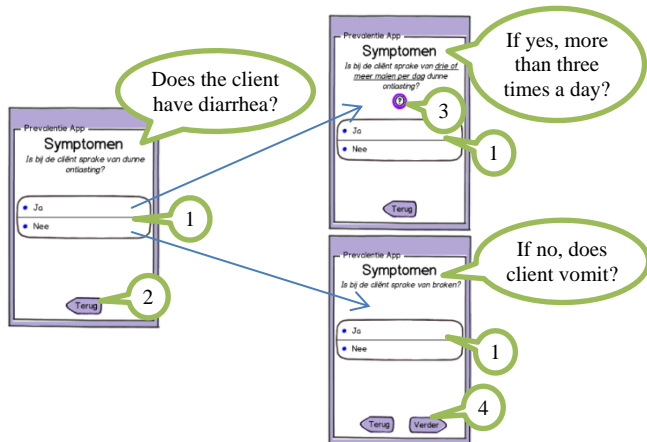


Figure 2. Part of the screens of the prototype used for Gastro-Enteritis; Example of Reduction: (1) Answer options: Yes / No; (2) Button to return to previous screen; (3) Help-button for additional information; (4) Button to continue to next screen.

As mentioned before, it was of great importance that registration would be faster and could be paused without losing data. To enable this, elements of *tailoring* are applied to the prototype, which allows the system to be tailored to (in this case) the usage context factors [13]. Every nursing home was given a unique log-in code and password. A physician had to log-in once, and was then able to continue registering their clients one after another. Moreover, when starting the system, physicians are given two options: to register a new client or to edit data of an existing client (see Fig. 3). For the latter, an overview was generated of all clients that had previously been registered by that specific

nursing home. Clients of other nursing homes are not shown.

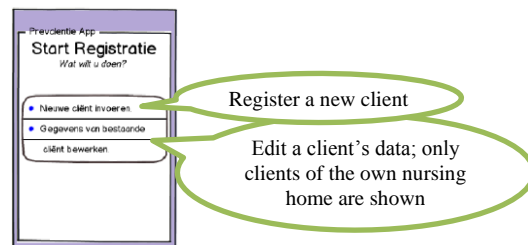


Figure 3. Example of a screen that leads to Tailored information

2) Dialogue Support

The prototype registration system requires physicians to indicate which pathogens caused an infection. However, during the user tests it became clear that within nursing homes, little funding is available to perform the laboratory tests to acquire this knowledge. Furthermore, if a laboratory test was performed at the moment of registration, its results were not always known yet. Therefore, in the final registration system, questions are added to ask whether a laboratory test was performed and whether its results were already known. If the latter question was answered with 'no' a pop-up screen appeared. This screen *reminded* [13] the physician that lab results should be added later.

Also, *suggestion* [13] is added to the final registration system. One example of the application of suggestion was used since physicians have to register all antibiotics that are used by their clients. However, the variety of antibiotics that exist is enormous and their names are complex. Initially, the intention was to let physicians scroll through an alphabetical list of all antibiotics (see Fig. 4).

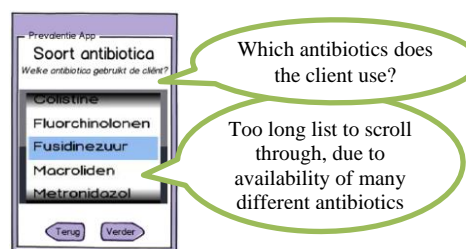


Figure 4. Example of the screen that subscribes the need for Suggestion

However, this was still too time consuming. Therefore, in the final registration system, a search system in which the physician enters the first three letters of the antibiotic is added. The system then automatically generates only antibiotics that start with these letters.

3) System Credibility Support

Finally, in healthcare in general and for the registration of healthcare-associated infections in nursing homes specifically, it is of great importance that the system is credible according to its users. Therefore, a website was created about the services provided by the registration system [15]. The Infection Manager website was developed

for the EurSafety Health-net project [16]. This is a large and successful European project involving many hospitals, microbiology laboratories and other healthcare institutions. The part of the website about the registration system consists of e.g. background information about the project and the parties that were involved in the development process. This was intended to give more clarity about the *trustworthiness* and *expertise* of the project and its project members [13].

Finally, in the final registration system, it was decided to add the EurSafety logo, to give the system more *surface credibility* [13].

D. Analysis of the User-Friendliness of the Prototype

Based on the scenario-tests, many major and minor adjustments had to be made in the mock ups. These concerned the clarity of wording, sequence of questions, completeness, user-friendliness, design and location of the buttons. For example, initially, there were two screens in our prototype for 'Aids', which asks whether the client uses any aids such as a catheter or tracheotomy; and 'Incontinence', which asks whether the client is incontinent. During the user-tests, the subjects had several comments about these screens. First of all, whereas we interpreted the term 'aid' as being a catheter of some kind, the subjects indicated that the term 'aid' to them meant 'walker' (see Quote 2). So, they suggested using a different term.

(Quote 2 – Originally in Dutch) “Yes, we use the word ‘Aid’ for something completely different. We use this word for walkers. So I would try to come up with a different word here.”

Furthermore, they found the screen about incontinence strange. In one of the scenarios, a client was described who had a catheter. The participants indicated that although incontinence is a possible reason for clients to get a catheter, they did not consider this client as being incontinent anymore (see Quote 3). They, therefore, said the option of having a catheter or stoma should be added to this screen.

(Quote 3 – Originally in Dutch) “You see, this client is not incontinent, but has a urethra catheter... So this is strange. You should add catheter here I guess. Because with a catheter you are not really incontinent anymore.”

As a result, the two screens were replaced by a new screen. This screen asks whether a client is incontinent. However, an additional answer option has been added, to indicate that a client has a catheter or stoma.

After the fourth user-test, no major issues were found anymore. Therefore, meetings with Information and Communication Technology (ICT) developers were held to further discuss the requirements for the registration system and to finally develop it.

IV. DISCUSSION

This study was aimed at determining whether user-centered and persuasive design could support a faster, easier, more fitting, more reliable and clearer registration of healthcare-associated infections by elderly care physicians. Regarding the design process, it can be said that the holistic approach using the CeHRes roadmap has provided the opportunity to not only develop an eHealth technology that fits the needs of its users and is successful in what it is intended to do, but to also make sure that it fits its context.

The constant and structural cooperation with end-users during the development process, gave us the opportunity to make it an iterative process. This means that it was possible to evaluate the eHealth technology in every stage of its development, and to (at any time) adjust the direction that it was going in. This aids in the development of an eHealth technology that fits its users' needs and context, and could potentially prevent high costs of re-design if major necessary adjustments are only found after final release of the technology.

Certainly, we still want to evaluate the speed, user-friendliness, fit with work processes, ease of use, clarity and persuasiveness of the final registration system. Thus, a summative evaluation is currently being planned. This evaluation will combine both qualitative and quantitative methods and will e.g. focus on user friendliness, speed of registration (both were found important by the end-users) and amount of errors that are made (important for the quality of the data). But for now, it can be said that the new system has already been used in two rounds of prevalence measurements, successfully registering over 3000 nursing home residents. It is web-based, and can therefore be used on any device capable of connecting to the world wide web. An example of a screen of the eventual registration system is given in Fig. 5.

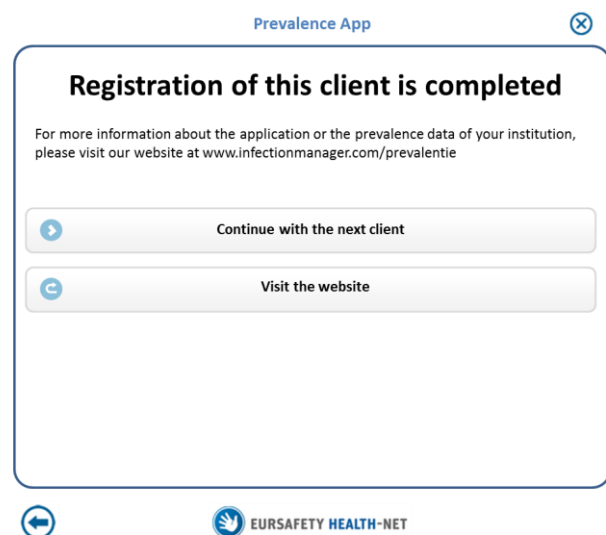


Figure 5. Example of the look and feel of the eventual registration system (Originally in Dutch)

A. Limitations

A limitation of this study is that it suffered from very strict and ambitious deadlines. This limited us in the amount of effort that we could put into the implementation stage of the development. Although this is thought to be a very relevant stage according to the CeHRes Roadmap, in this project its influence might be limited. The elderly care physicians who are the end-users of the registration system in this study, are obligated to use it if their nursing home participates in the prevalence measurements.

Another possible limitation might be that our study had a relatively low number of participants. However, aim of this study was solely the development of an eHealth technology, not to perform an evaluation of its effects.

Also, this project concerned an already existing intervention. Question was, whether technology can aid in its optimization. The context was, however, explored: regulations and conditions for use of the technology and the fit with existing systems for processing the data have been studied in this project.

Finally, the given setting for this project (nursing homes) presented us with its very own challenges. The opportunities for using technology were limited, because of the technological infrastructure of Dutch nursing homes (wherein often outdated PCs are used), and the degree to which people are used to working with technology (e.g. only 47,1% of the physicians used a smartphone). However, this gave us an interesting opportunity to put ourselves and the possibilities of the CeHRes Roadmap to the test, to see how it and how we would cope with such limitations.

V. CONCLUSION

This article goes beyond the mere development of eHealth technologies. It has subscribed our strong believe that involving end-users in all stages of development is of paramount importance for the creation of successful eHealth technologies, because (1) it gives insight in the needs and wishes of the end-users, that have to be met by the eHealth technology; (2) end-users are able to give feedback on both details (the location of a button) and on the bigger picture (the clinical practice that the technology has to be used in); (3) it allows for the development to be an iterative process, which may prevent costly redesign to be necessary; and (4) although they might have used their own words to express themselves, end-users appeared to have very clear ideas about the their needs regarding Persuasive Systems Design.

ACKNOWLEDGMENT

This project was funded by the Interreg IV “EurSafety Health-net” project. We also thank the elderly care physicians who participated in this study.

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