Available online at www.sciencedirect.com
ScienceDirect
Int. J. Human-Computer Studies 68 (2010) 328–343
International Journal of Human-Computer Studies
www.elsevier.com/locate/ijhcs

From expert-driven to user-oriented communication of infection control guidelines

Fenne Verhoeven[a,*], Michaël F. Steehouder[a], Ron M.G. Hendrix[b], Julia E.W.C. Van Gemert-Pijnen[a]

[a]*University of Twente, Faculty of Behavioral Sciences, Department of Technical and Professional Communication, PO Box 217, 7500 AE Enschede, The Netherlands*

[b]*Laboratory for Clinical Microbiology, PO Box 377, 7500 AJ Enschede, The Netherlands*

Received 13 November 2008; received in revised form 26 June 2009; accepted 22 July 2009
Available online 30 July 2009

Abstract

Currently, infection control guidelines in hospitals and other health care institutions are more expert-driven than user-oriented. In order to enhance the usability of the expert-driven guideline format, we developed a website for the communication of existing guidelines that better fit the practical information needs of health care workers (HCWs). We employed a user-centered design process that involved two studies.

In the initial study, 28 HCWs were asked to solve tasks using existing, paper-based infection control guidelines. In order to detect their strategies and problems, the participants were asked to think aloud. Usability problems occurred due to poorly structured information, insufficient quality of information, and a mismatch between experts' and HCWs' vocabulary. To overcome these shortcomings, three design principles were applied for communicating infection control guidelines: better navigation (the guidelines should be searchable in several ways); multimodality (the guidelines should not be presented as text only), and action-orientation (the guidelines should be presented as HCWs' behaviors). A website was developed to meet these principles.

In the second study, the same 28 HCWs completed tasks identical to those of the first study while thinking aloud, but this time using the website. The percentage of correctly completed tasks increased and the mean time for task completion decreased significantly. Also, respondents were more satisfied with the website than the paper-based guidelines. The number of problems due to poor information quality and a mismatch in vocabulary declined, although the number of structural problems increased. This can probably be explained by the fact that the navigation structure was user-generated (using Card Sort), in contrast to a standardized answer format based on common usability principles.

Overall, we found that involving HCWs in the development process is important to create a sense of ownership and to foster the implementation of the guidelines, which might eventually result in compliance and reduce health care-associated infections. This paper outlines concrete steps for how to involve HCWs in the design process.

Keywords: User-centered design; Usability; Infectious diseases

1. Introduction

Health care-associated infections cause thousands of preventable deaths each year (Pittet and Donaldson, 2006). Therefore, it is crucial that health care workers (HCWs) comply with infection control guidelines. The purpose of infection control guidelines is to educate health care workers about the direction on the prevention and control of infectious diseases and uphold standards of safe work practice. Although most HCWs are aware of the rationale for infection control practices, compliance is generally poor (Berhe et al., 2005). In addition to behavioral determinants such as management values and workload, the insufficient tailoring of infection control guidelines as a communication means to HCWs' needs might account for low

*Corresponding author. Tel.: +31 53 489 4441; fax: +31 53 489 4259.
E-mail address: f.verhoeven@utwente.nl (F. Verhoeven).

1071-5819/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijhcs.2009.07.003

compliance rates (Sachs, 2006). Previous research has demonstrated that HCWs repeatedly encounter problems with the usability of the guidelines, which could be detrimental to their uptake in clinical practice (Van Gemert-Pijnen et al., 2005).

The problem with infection control guidelines as a means of communication is that they are expert-driven. Expert-driven guideline communication can be characterized by a strong focus on scientific validation, regulation, and legislation (AGREE Collaboration, 2003). In the design process, higher priority is given to a consensus on content-related issues among experts than to HCWs' practical information needs. This can make the document difficult for individual HCWs to use as a resource and to identify procedures for daily work practice (AGREE Collaboration, 2003; Van Gemert-Pijnen et al., 2005). HCWs' tacit knowledge, which is context-dependent and made up of the practical and experiential wisdom of individual HCWs, is rarely taken into account in the development of guideline communication. As a result, infection control guidelines as a means of communication are insufficiently targeted to HCWs' norms and values, are hard to use, and eventually evoke reluctance and disregard on the part of the HCWs (Saillour-Glenisson and Michel, 2003; Shekelle et al., 2000).

A possible solution to enhance the usability of the expert-driven guideline format is to communicate the existing, evidence-based guidelines in a format that better fits the practical information needs of the HCWs. Presenting guidelines on a website facilitates the inclusion of hyperlinks to additional resources and multimodal functionalities, such as instructional videos. Consequently, in-depth information can be available without affecting the guidelines' conviviality (Fervers et al, 2005). The development of a website allows the direct involvement of HCWs, which can lead to a higher level of usability. In a user-centered design process, HCWs will be invited to make their tacit knowledge concerning infection control explicit, stimulated to make their own decisions about directions and strategies for improvement, and are led in those actions (McCoy et al., 2001; Murphy, 2002; Van Gemert-Pijnen et al., 2003). Considering usability prior to development of a first prototype of a website may prevent uncovering pitfalls in the system after its implementation, which can be costly and avoid reluctance among intended users (Thomas and Bevan, 1996).

Various research methods are available to develop communication means with a high level of usability. These methods can be divided into usability *testing* and usability *inspection* (Holzinger, 2005; Hom, 1998; Jaspers, 2009; Nielsen, 1993). In usability *testing*, representative users work on typical tasks using the system (or the prototype) and the evaluators use the results to see how the user interface supports the users to do their tasks. The most common employed methods are thinking aloud, field observation, and questionnaires (Holzinger, 2005). In usability *inspection,* usability specialists and sometimes software developers or other professionals, examine usability-related aspects of a product or system. Various inspection methods are available, such as heuristic evaluation, cognitive walkthroughs, and action analysis (Holzinger, 2005). Since it is often thought that experts are not able to identify real user problems (De Jong and Lentz, 2006), and we assumed that problems with the quality of guideline communication were particularly caused by their expert-driven character, we opted to perform usability *testing.* Of the available methods for usability testing, we selected thinking aloud. Of all usability testing methods, thinking aloud has been most often used in the health care domain (Jaspers, 2009). Thinking aloud involves having an end user continuously verbalizing thoughts while using a system, which provide insight into the underlying causes for usability problems and requirements for improvement (Holzinger, 2005; Jaspers, 2009; Nielsen, 1993).

In this paper, we will first describe an initial study that diagnosed the usability problems HCWs encountered while using existing paper-based guidelines. Next, we will describe three general design principles for the communication of infection control guidelines based upon the findings of the first study. Then we will describe how, according to these principles, the content of the paper document was converted into a website. Subsequently, we will present the results of the second study, in which HCWs worked with a test version of the website. This second study also served as a formative evaluation of the website before it was launched online, with the purpose of "test running" various aspects of the website and to verify whether the design team did not miss any errors. The usability issues raised by this study were solved prior to the website's launch. Finally, we will compare the two communication modes in terms of efficiency, effectiveness, and satisfaction rates. Ultimately, our study resulted in the creation of a website that facilitates HCWs with usable infection control guidelines that enhance the decision-making process to deliver safe health care.

2. Methods

2.1. Research context

Due to increased international trade in health services, Methicillin Resistant *Staphylococcus aureus* (MRSA) is one of the organisms that most commonly contributes to the rapid spread of health care-associated infections (Pittet and Donaldson, 2006). The Dutch–German research project EUREGIO MRSA-net Twente/Münsterland addresses this problem at a cross-national level, and the study reported here was conducted as part of this project (Friedrich et al., 2008). Therefore, MRSA guidelines served as an ideal case for study. The study was performed in one Dutch and one German hospital in the border region, with capacities of 1070 and 1500 beds, respectively. The first study was performed in June 2006; the second took place in July 2007. The two studies reported in this paper were part of a user-centered

design process aimed at the gradual development, implementation, and evaluation of a website with MRSA guidelines (Kinzie et al., 2002). The studies reported here were part of the development phase, next to a content analysis of existing guidelines (Verhoeven et al., 2007), a Card Sort Study ($n = 10$) that generated the website's menu structure, and prototyping interviews ($n = 14$), which led to the website's final lay-out (Verhoeven et al., 2008). After the website's launch, we identified factors affecting successful adoption of the website among health care workers (Verhoeven et al., 2009), and the position of the website among other online sources about MRSA. In each phase of this user-centered design process, the sample included physicians, nurses, and nursing assistants.

2.2. Research design

In the initial study, 28 HCWs (4 nursing assistants, 16 nurses, and 8 physicians) were asked to complete MRSA-related tasks using the existing paper-based MRSA protocol enforced in their hospital at the time of the research, while thinking aloud. The protocol consisted of a 50 pages, one-sided printed document, including a table of contents that comprised the title and page numbers of the various chapters. The protocol did not include any additional navigation aids, such as an index. The findings from this initial study gave us insight into usability problems HCWs faced when using a paper-based document. Based on the results, three general design principles were formulated. We revised the presentation and structure of the document according to these principles, which led to a test version of the website. The website's functionalities and navigational structure can be found in Table 2. In the second study, the same 28 HCWs completed the identical set of tasks as in the first study while thinking aloud again, but now using the test version of the website. This second study aimed to verify whether the website overcame the problems observed in the initial study and to detect any missed errors before the website was implemented online (Figs. 1–3).

The participants were asked to think aloud while performing the tasks. Thinking aloud is a widely used method for testing the usability of software, interfaces, websites, and (instructional) documents. The basic principle of this method is that potential users are asked to complete a set of realistic tasks with the tool tested, and to constantly verbalize their thoughts while working on the tasks. The method has high face validity since the data obtained reflect the actual use of the tool and not the participants' judgements about its usability (Krahmer and Ummelen, 2004; Van den Haak, 2008).

In our study, the tasks consisted of *what if*-tasks. A total of 27 different tasks were formulated, together representing all categories of the MRSA guidelines by the Society for Health care Epidemiology of America (SHEA) (Muto et al., 2003), which include surveillance cultures, hand washing procedures, contact isolation procedures, minimizing cross-contamination procedures (isolating, cleaning), and eradication (antibiotic treatment). A few task examples are:

- You are attending to an MRSA patient in an isolation room. Using the guidelines, can you say aloud which preventive measures you must take in order not to

Fig. 1. Screenshot of the website with practical, action-oriented content.

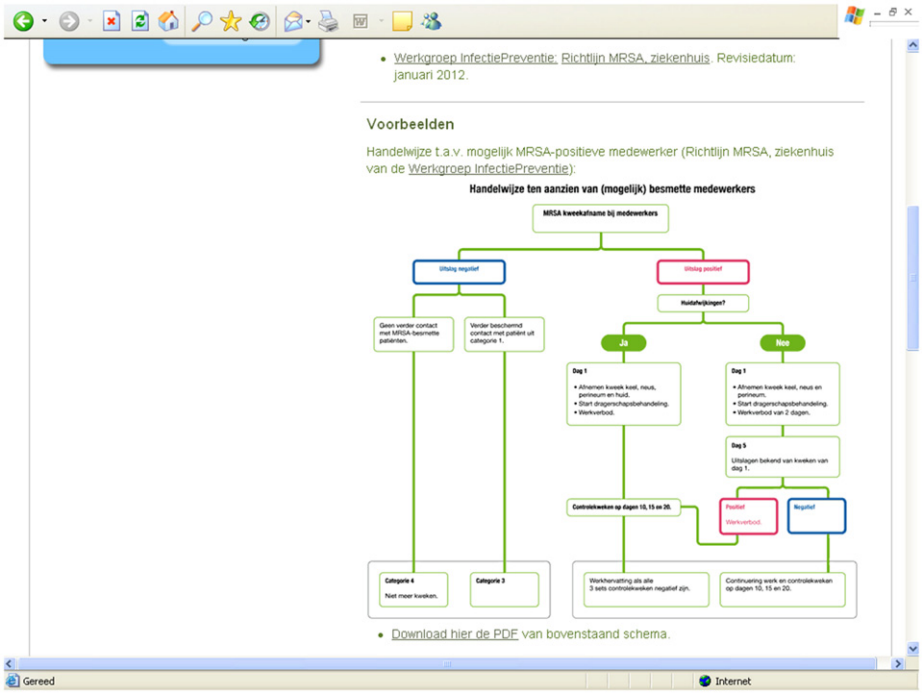

Fig. 2. Screenshot of the website with guidelines presented in a multimodal way.

Fig. 3. Screenshot of the website with three search options.

transmit MRSA to other patients or personnel? (SHEA category: contact isolation procedures);

- You have been colonized with MRSA yourself and the results of the first screening cultures are negative. Using the guidelines, can you say aloud whether you can restart your working activities again? (SHEA category: surveillance cultures);
- You want to treat an MRSA patient against MRSA colonization. Using the guidelines, can you say aloud what you need to do? (SHEA category: antibiotic treatment).

The tasks were validated by one Dutch and one German medical microbiologist, who also defined the correct task

outcomes. A task was considered to be completed successfully if a HCW found the right solution to the task independently, without help from the test administrator. Van Gemert-Pijnen et al. (2003, 2005) already demonstrated this method to be valid. Each participant carried out at least one task from each SHEA category. The order of the tasks was permutated among respondents in order to both (1) ensure that each task was performed an equal amount of times among all respondents, and to (2) reduce possible learning effects caused by respondent's memory about the guideline content gained during performance of earlier tasks.

We used the concurrent thinking-aloud technique proposed by Ericsson and Simon (1980), which implies that the test administrator gives non-directive reminders to continue verbalization after 15–20 s of silence. Some doubts have been raised about validity and reliability of the thinking-aloud technique, but this critique focused on thinking aloud as a technique to study cognitive processes rather than to identify usability problems (Boren and Ramey, 2000). A more relevant question is the influence of thinking aloud on task performance time. Concurrent thinking aloud tends to increase the time required to arrive at a solution compared with silent controls, presumably because of the extra time required to verbalize. Extensive research, reviewed by Ericsson and Simon (1993), indicated that direct concurrent thinking aloud does imply some slowing of performance, but probably has no reactive effect. Moreover, it is likely that the delay in task performance caused by thinking aloud is not variable within subjects, and since we applied a within-subjects design (the respondents were exposed to both conditions), the issue of the influence of response time on task performance becomes less significant.

The study was conducted in a silent, isolated room in the hospital ward where the participant was employed and lasted strictly 1 h. No time limit was imposed on the respondent to work on a task, implying that respondents performed as much tasks as they could during 1 h. The tests were audiotaped with prior consent of the respondents and were transcribed verbatim afterwards.

2.3. Study population

We included 14 Dutch and 14 German participants in our sample, yielding a total sample size of 28. Participants were recruited on a voluntary basis. Eligible HCWs were at least 18 years old and Dutch- or German-speaking. They did not need to have prior knowledge or experience with the use of either paper- or web-based infection control guidelines. 15 of the respondents were male, 13 were female, and altogether had a mean age of 38.2 years (range 24–57). The majority ($n = 16$; 57.1%) used the Internet more than twice a month to retrieve work-related information.

Every respondent in this sample participated in the study with the paper document as well as in the study with the website. In other words, the exact same set of individuals was involved in the first study as in the second, so the results can be validly compared. Because of the long time between the two studies (over 1 year), a test–retest effect is unlikely.

2.4. Outcome measures

The main standard that provides guidance on usability is ISO 9241, which describes usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (International Organization for Standardization, 1998).

In a review of 180 studies on usability, Hornbæk (2006) provides an overview of existing measures employed to measure usability. He classified the measures into the three groups effectiveness, efficiency, and satisfaction of the ISO 9241 standard. The typical measures to evaluate the concepts are:

- *Effectiveness*: task completion, accuracy, recall, completeness, and quality of outcome;
- *Efficiency*: time, input rate, mental effort, usage patterns, communication effort, learning measures;
- *Satisfaction*: preference, satisfaction with the interface, and attitudes and perceptions.

Several of these measures were included in our study (see Table 1). These indicators can be applied to measure the usability of nearly every document or object. Actually, usability testing has frequently been employed to investigate the usability of paper-based instructional communication (e.g., Gould and Lewis, 1985; Loorbach et al., 2007). This justifies the application of the identical usability measures to both the paper document (study 1) and the website (study 2).

Effectiveness is defined as the accuracy and completeness with which users achieve certain goals (Frøkjær et al., 2000). According to Frøkjær et al. (2000), indicators of effectiveness include task completion and information problems. We used task completion as the primary, objective indicator of effectiveness by scoring for each task to what degree it was accomplished successfully (fully, partially, or not at all). These judgments were verified by the two medical microbiologists who validated the tasks (see Section 2.2). A second measure of effectiveness was the number of problems related to information quality that arose while HCWs worked with the guidelines. Information quality problems can be related to incompleteness, incomprehensibility, or inaccuracy (Bennett et al., 2004; Van Gemert-Pijnen et al., 2005). During analysis, two other types of information problems emerged: inadequate information structure and matching problems. We identified information problems by closely studying verbal indicators or problems experienced by HCWs (Van den Haak, 2008).

Table 1
Usability components and outcome measures.

Usability component	Subconstruct	Outcome measures[a]	Data source
Effectiveness	Task completion	Fully, partially, or not completed successfully	Observation
	Navigation problems	Number of encountered difficulties with navigation structure and arrangement of information	Verbalization
	Matching problems	Number of encountered problems due to matching between user's and expert's vocabulary	Verbalization
	Information quality problems: incompleteness	Number of encountered problems due to incomplete information	Verbalization
	Information quality problems: incomprehensibility	Number of encountered problems due to incomprehensible information	Verbalization
	Information quality problems: inaccuracy	Number of encountered problems due to inaccurate information	Verbalization
Efficiency	Time	Number of seconds needed to complete task	Observation
	Effort	Number of actions needed to complete task	Observation
	Search strategy: orienteering	Frequency with which this strategy is applied	Observation
	Search strategy: teleporting	Frequency with which this strategy is applied	Observation
Satisfaction	Design	Number of expressions related to construct	Verbalization
	Content	Number of expressions related to construct	Verbalization
	Features	Number of expressions related to construct	Verbalization

[a]Both expressed in number of tasks during which problems were faced as well as in number of respondents who encountered the problem.

Efficiency is defined as the time and effort with which users achieve certain goals (Frøkjær et al., 2000). We measured the time aspect by registering the number of seconds HCWs spent navigating to and interacting with the content. Effort was measured by recording the number of actions it took a respondent to complete a task. In the first study, where HCWs worked with paper documents, an action was defined as a page-turn or starting to read a new section on the same page out loud. In the second study, an action was defined as a mouse-click (on a hyperlink) or entering a search term in the search engine. Since respondents used a different communication mode in each study, the number of actions cannot be compared validly; turning 40 pages in a paper-based document demands a higher cognitive load than clicking on a hyperlink. However, we did count the number of actions in both communication modes in order to have a rough indication of their extraneous cognitive load (Chandler and Sweller, 1991). Cognitive load theory claims that the attention and working memory of an individual are limited. The extraneous cognitive load, which concerns cognitive demands during learning and do not foster the actual objectives of the learning material, is generated by the manner in which information is presented to learners and is under the control of the designers (Holzinger et al., 2009; Pollock et al., 2002). Extraneous cognitive load can be attributed to the design of the instructional materials, such as cross-references or navigation elements.

As an additional measure of efficiency, we examined whether HCWs employed different information retrieval strategies when faced either with the paper document or the website. We registered every action respondents undertook during task performance. This generated behavioral data used to analyze HCWs' information retrieval strategies. We identified two main search strategies: orienteering and teleporting. *Orienteering* involves reviewing both prior and contextual information to narrow in on the actual information target, often in a series of steps, without specifying the entirety of the information needed up front. *Teleporting* concerns jumping directly to the information target (Teevan et al., 2004). Teleporting is a more efficient strategy, as the user does not have to react to stimuli from the medium, which takes more time and effort. We coded a respondent's search strategy as orienteering if it took more than one action to retrieve the relevant information, and we assumed respondents teleported when they needed only one action to achieve their goal.

Satisfaction includes the users' comfort with and positive attitudes towards the use of the guideline format. We assessed satisfaction by analyzing both participants' verbal utterances during task performance (think-aloud data), next to their overall opinion concerning the communication means' usability (which we asked after they finished the tasks). Expressions were related to design, content, and features of the communication means. We did not use a standardized instrument, as questionnaires can only confirm known variables and assess their scores; no valid, standardized instrument was available to compare satisfaction of paper- and web-based communication (Van Velsen et al., 2008).

2.5. Analysis

The respondents had to solve identical tasks in the first and second study. The number of completed tasks, however, differed between the two studies; the respondents appeared to finish more tasks in the second study (when working with the website). As the tasks differed considerably in their nature (see Section 2.2), only the tasks that were performed by a respondent both in the first and the second study were involved in the analysis.

Data from one randomly selected transcribed thinking-aloud test were analyzed independently by two researchers (FV, JvG) using deductive analysis, implying that the coding categories were derived from the conceptual framework presented in Table 1 (Patton, 1990). Half of the coding categories involved observations made by the researcher, whereas the other half concerned respondents' verbalizations. Repeated or reworded descriptions of the same problem were only counted once per task. Disagreement was solved by discussion after jointly reviewing the fragment. Subsequently, all transcribed data were coded by the principal investigator (FV). Overall, 1381 fragments of verbalization concerning effectiveness, efficiency, and satisfaction were identified. Since the data set was too large to have it reviewed independently by two researchers, a random selection of 5% of all coded fragments was coded by a second independent researcher (JvG). Agreement on categorization of the problems and requirements was satisfactory (Cohen's $\kappa = .78$) (Landis and Koch, 1977).

In order to conclude whether the website enabled the users to retrieve the required information more effectively (rate of successfully completed tasks) and efficiently (the number of seconds and the amount of actions to complete a task) compared with the paper document, paired samples T-tests were carried out using SPSS 16.0. To detect significant differences between the type of information problems and search strategies that occurred in both conditions, χ^2-tests were conducted.

3. Results

This section is divided into four parts. First, we present a qualitative description of the problems HCWs encountered while using the paper document (in study 1), then we describe how these findings were used to design the website. Subsequently, we describe the problems that were encountered while participants used this website (in study 2). Finally, we present quantitative data to compare the two methods of communicating infection control guidelines.

3.1. Problems with the paper document

More than half of the performed tasks were not completed successfully. Furthermore, it took the respondents an average of 383 s (6 min) to finish a task. Given that in reality, HCWs abandon a search after about 2 min, the effectiveness and efficiency of the paper document can be rated as low (Yu et al., 2007). The observations and the think-aloud verbalizations made clear what the main problems were.

3.1.1. Effectiveness problems

Approximately one third of the usability problems were due to a mismatch between the experts' and the HCWs' vocabulary (see Table 4). For instance, a respondent looked for the word "treatment" in the table of contents, whereas the guideline document used the word "decolonization therapy".

Many other usability problems were caused by the poorly structured information in the paper document. These problems were mainly faced during the "examine results" phase (Marchionini, 1995). This is the phase during which respondents examined relevant sections of the document to identify whether or not it contained the required information. Respondents expected to find the required information in a particular section or by employing a specific navigation strategy, but the opposite appeared to be true:

> Now I have to read the complete index. An alphabetically ordered-index would make it more practical, so I can immediately and more quickly find what I need. (Respondent 11, German, nurse)

Other examples of information structure problems that were encountered with the paper document, are:

- Difficulties with finding specific pages;
- Lack of list-wise presented information;
- Lack of decision trees;
- Lack of tables;
- Little space between the lines.

The low effectiveness rate seemed to be mainly caused by insufficient quality of information. Information appeared to be inaccurate (procedures were outdated or different from HCWs' tacit knowledge), incomprehensible (containing professional jargon and unclear procedural information), or incomplete. The latter was the largest hindrance to successful task completion. Respondents indicated that the paper document was too concise to enable them to make a safe decision for clinical practice, as the following quote illustrates:

> So this guideline only says that I'm not allowed to perform activities involving direct and indirect patient contact. I don't know what indirect contact means. Where it begins and where it ends. Generally speaking, everything that we do involves indirect patient treatment. Therefore I don't know whether I'm allowed to work here on the ward, or down in the archive, or-yes, that's not clear to me. (Respondent 9, German, nurse)

Additionally, respondents wished for more practical information, particularly guidelines related to

MRSA-positive HCWs:

> If a patient is colonized with MRSA, the medical microbiologist is responsible. And then the protocol serves as a manual for what to do. But for MRSA-positive staff, there is nothing. (Respondent 11, Dutch, nurse)

Overall, the information problems provided us with 167 additional key questions that were not answered by the paper document, but their answers are nevertheless required for HCWs to deliver safe health care. To mention a few:

- In what order should I put on and take off personal protective equipment?;
- Which materials should I throw away after discharge of an MRSA-positive patient from an isolation room?;
- An MRSA-positive patient should be transported from one ward to another within the hospital. Which personal protective equipment should I wear when accompanying this patient?

3.1.2. Efficiency problems

Respondents particularly applied an orienteering strategy when using the paper document. Every respondent employed this strategy during one or more tasks, particularly when they encountered difficulties with translating the task into a meaningful search question, or had no particular idea about where to find the required information. In such an event, the participant started to review the different sections of the guidelines (e.g., by means of the table of contents) and checked each section for its possible relevance, which required much of the respondents' time (on average, nearly 6 min per task).

Teleporting, a more efficient search strategy, occurred less frequently (see Table 5). Teleporting was mainly performed when the respondent remembered having read about the topic earlier, while solving a previous task. This required a high mental effort from the users, as they had to rely on their memory in order to solve tasks. Sometimes, both strategies were combined: participants commonly fell back on the orienteering strategy after an instance of ineffective teleporting.

3.1.3. Satisfaction problems

Satisfaction refers to the users' comfort with and positive attitudes towards the use of the guideline format. During task performance, several respondents verbalized feelings of annoyance or frustration regarding the design:

> I can't find it again. The fact that I've been searching for ten minutes now and still do not know for sure that the answer is right, that is not good! (Respondent 7, Dutch, physician)

Other important verbalizations concerned dissatisfaction with the absence of information presented in list form ($n = 4$), important information not printed in bold ($n = 3$), and the absence of tables ($n = 7$) and tree diagrams ($n = 5$). One respondent suggested the solution of providing several search options that consider the different search strategies that people use:

> A table of contents and an index… Like in a book. Most people are acquainted with that, so an index should be in the back. And a table of contents in the front. And then each chapter should be considered a separate category. (Respondent 10, Dutch, nurse)

Furthermore, participants believed that the guidelines should more explicitly communicate what one should or should do not in a particular situation ($n = 15$). Guidelines should be "clear and concise" ($n = 14$) and "contain stone-hard facts".

3.2. Designing the website

Our belief that a web-based format would improve the usability of the guidelines (see Section 1), was strengthened by the findings of study 1. Although information quality problems (inaccuracy, incomprehensibility, and incompleteness) could have easily been prevented by solely improving the information and maintaining the paper-based format, the (1) mismatch and (2) "information structure" problems could be more optimally addressed via a website. (1) A content management system would enable the design team to add and delete keywords to the search engine's database that aid in matching system's with HCWs' vocabulary, and (2) a web-based format would allow the inclusion of combining several search options (search engine, categorical search, frequently asked questions) and could aid to enhance the clarity of the information structure, like a breadcrumb trail.

We formulated three general principles for the improved communication of infection control guidelines, based on our understanding of HCWs' problems with the paper document that resulted from study 1. These principles are presented in Table 2 with some examples of how they were applied to the website. An extensive system description has been published elsewhere, including a description of the user-centered design process (Verhoeven et al., 2008). Two design principles involve effectiveness and one encompasses efficiency. We assume that enhancement of effectiveness and efficiency will indirectly imply a higher user satisfaction. We would like to emphasize that we did not change the content of the guidelines. Rather, we reformulated them in a more instructional style, used words that were more familiar to the HCWs, presented the guidelines multimodally, and presented them in a structure that enables a more efficient search strategy.

3.3. Problems with the website

Nearly 90% of performed tasks were completed successfully. It took the respondents an average of 132 s to finish a task.

Table 2
Design principles for user-centered guideline communication based on study with expert-driven guideline communication ($N = 28$).

Usability component	Design principle	System description	Example
Effectiveness	**Add practical, action-oriented content** (in order to avoid information quality problems), **communicated in HCWs' vocabulary** (to prevent matching problems)	The 167 additional key questions that emerged from the initial study served as input for the content of the user-centered guideline communication. Answers were based on national MRSA guidelines (Dutch Working Party on Infection Prevention, 2005; Committee for Hospital Hygiene and Infection Prevention at the Robert Koch Institute, 1999), and were complemented and actualized by the Dutch and German medical microbiologists involved in the research project. In order to cater the guidelines' content to HCWs' vocabulary, the user-centered website used words such as "get rid of MRSA" instead of "eradication therapy", "take swabs" instead of "perform screening cultures", "outbreak" rather than "epidemic situation", etc. A dedicated content management system enabled the project team to add and delete keywords to the search engine's database that aid in matching system with HCWs' vocabulary.	Fig. 1
Effectiveness	**Present guidelines in a multimodal way** (in order to overcome information structure problems)	Each of the 167 additional key questions was answered according to a standardized format based on usability guidelines, with important items placed consistently at the top center Scroll stoppers were avoided as much as possible and moderate white spaces were used (Koyani et al., 2006). Each answer comprised a title, a short answer, an instructional video, comments, and (scientific) references such as newspaper articles, links to other websites for further reading, and multi-media examples. In order to keep information accurate, revision dates and the latest news were included. Furthermore, visual aids such as tables and tree diagrams were added.	Fig. 2
Efficiency	Consider different search strategies HCWs employ by **incorporating three search options**	In order to make the search process more efficient, the system should allow the user to rapidly switch from one search strategy to another and the user should always be able to keep track of his/her location within the system. Therefore, answers to questions were retrievable through a search engine, a menu structure with categories, and frequently asked questions. We also incorporated a breadcrumb trail. The incorporation of three search options and a breadcrumb trail enable HCWs to teleport and therefore find the relevant information more rapidly with less effort (i.e. more efficient).	Fig. 3

3.3.1. *Effectiveness problems*

Although the number of encountered matching-, completeness-, and accuracy-related problems dropped considerably when HCWs worked with the website (see Section 3.4), an equal number of usability problems occurred during both studies. This seemed to be due to an increase in problems related to information structure. Whereas HCWs in the first study mainly faced information structure problems during the "examine results" phase, they now experienced information structure problems mainly throughout the "reflect, iterate, stop" phase. In this stage, HCWs already supposed to have detected the relevant information, but had problems when reading the answer to the question in more detail. The most important problem was that respondents did not understand how to navigate within and away from the answer section:

> So this answer suggests the patient has to be treated in isolation… Isolation measures, protective measures. Clean up and disinfect isolation room. Remove laundry and clinical waste according to special procedure…. And then it says: Information about screening and treatment of an MRSA-colonized or infected patient can be found in the Category "Screening" and "Treatment". Well, where should I look then? (Respondent 4, Dutch, nurse).
>
> The answer says 'screening of high-risk patients' and then which sites you have to sample. Oh, I've seen that earlier, hmm… Can I go back? (Respondent 3, Dutch, nurse).

Furthermore, respondents expected more hyperlinks to additional sources:

> Hospitalized patients should be treated in isolation. Yes, that is what I was looking for. Notification obligation. I'll click on this word. Can I click here? Oh, I can't click. (Respondent 3, German, nursing assistant)

Other examples of information structure problems encountered with the website, are:

- Search options being unnoticed;
- Information not separated for different occupational groups;
- Lack of a link to a Portable Document Format version of the page;
- Lack of a print button.

3.3.2. *Efficiency problems*

Respondents used the teleporting strategy more often than the orienteering strategy when working with the website. The lower frequency of teleporting with the use of the paper document might be due to the difficulty of creating a clear mental model of its structure (users are not able to view all pages simultaneously), whereas the transparent interface of the website permitted the respondents to continuously keep track of their position within the system. The various search options, including the table of contents in the category section, were continuously

visible to the user. This possibly enabled the user to create a clear mental model of the system structure.

3.3.3. Satisfaction problems

HCWs uttered several expressions of satisfaction with the website. Several HCWs seemed to appreciate the practical-oriented content:

> I've tried several times to find clear guidelines on our Intranet, but it always contains lengthy declarations about nearly everything and it is almost impossible to comb through. But here, on this website-for instance with the cutlery and the clinical waste-it is described clearly: How one should handle it, and that's it. Not so long-winded. So you know immediately what to do. (Respondent 14, German, physician)

Furthermore, the website's efficiency was perceived as very positive:

> Well, this website works out much better than the paper protocol. That was a whole show of page-turning. I would say this is a major improvement. (Respondent 7, Dutch, physician)

However, the task completion time in the user-centered condition was still not appreciated by all participants. One respondent remarked, after having completed the task successfully within 33 s, "Wow, that was very hard to find." (*Respondent 14, Dutch, physician*). This might be due to the great expectations respondents hold regarding the speed with which Internet-based tools function.

3.3.4. Problem solving

Study 2 also was intended to "test run" various aspects of the website and to verify whether the design team did not miss any errors. Missed errors appeared to be the lack of including hyperlinks when relevant, the difficulties that respondents encountered with navigating in and away from answer pages (see Section 3.3.1), and the website's slow speed, as perceived by several respondents (see Section 3.3.3). These issues were solved before the website was officially implemented online: more hyperlinks were incorporated, an instructional text regarding website use and the website's objective was made accessible via an "About this website" button, and we limited the log file size growth in order to speed up the web pages' load time.

3.4. Comparison of the paper document and the website

3.4.1. Comparison of the effectiveness outcomes

The website enabled HCWs to complete significantly more tasks successfully compared with the paper document ($p<.001$) as shown in Table 3.

The number of usability problems did not substantially decrease when HCWs used the website (270 versus 242 problems, as seen in Table 4). The only significant difference concerned matching problems ($p<.05$). However, the type of problems encountered by the HCWs differed considerably.

The increased effectiveness of the website seemed to be caused mainly by the inclusion of practical, action-oriented content communicated in HCWs' vocabulary, and by incorporating different search options, as the number of matching and information quality problems dropped in the website environment. Remarkably, the number of problems related to information structure doubled when HCWs worked with the website, although this difference was not significant. This is probably due to the fact HCWs spent less time navigating to the answer, but they spent more time with the content once the answer was detected, leading to a scenario in which many structural problems arose, such as figuring out how to navigate within and away from the answer. In other words, because the website enabled users to achieve the learning performance within a smaller time frame, more time was available for exploring the underlying information, implying more recognition of problems with the presentation of information (Holzinger et al., 2009).

3.4.2. Comparison of the efficiency outcomes

Efficiency is only a relevant quality criterion if the communication is effective (saving time to find an incorrect solution does not make any sense). Therefore, we computed the task completion time for successful completed tasks only. The mean completion time per task was 383 s with the paper document versus 132 s in the web-based condition. The website thus allowed the HCWs to complete a task over 4 min faster (251 s) than the paper document ($p<.001$). The action criterion, however, led to different results. The respondents had to perform more actions in order to complete a task in the web-based environment than in the paper-based environment: 3.9 versus 3.0 actions. Table 5 shows the search strategies HCWs employed when using each communication style.

As can be seen in Table 5, the less efficient, time-consuming orienteering strategy was employed significant less frequently with the website compared with the paper document ($p<.05$). On the contrary, the website allowed

Table 3
Overview of successfulness of completed tasks with paper document in study 1 and website in study 2.

	Paper document		Website	
	N	%	*N*	%
Completed successfully	67	47.5	124*	87.9
Completed partially successfully	14	9.9	10	7.1
Completed unsuccessfully	60	42.6	7	5.0
Total	141	100	141	100

Note: The paired samples *T*-test was used to detect significant differences between the two conditions. Time between studies was 13 months.
*$p<.001$.

Table 4
Overview of information problems with paper document versus website.

Problem type	Paper document				Website			
	Tasks ($N = 141$)		Respondents ($N = 28$)		Tasks ($N = 141$)		Respondents ($N = 28$)	
	%	n	%	n	%	n	%	n
Mismatch between HCWs' and experts' vocabulary	53.9	76*	100.0	28	34.8	49	82.1	23
Information structure	29.1	41	92.9	26	48.9	69	71.4	20
Incompleteness of information	60.3	85	96.4	27	44.0	62	82.1	23
Inaccuracy of information	24.1	34	75.0	21	14.9	21	39.3	11
Incomprehensibility of information	24.1	34	71.4	20	29.1	41	75.0	21
Total		270				242		

Note: χ^2 was computed to detect significant differences between the two conditions. Time between studies was 13 months.
*$p < .05$.

Table 5
Overview of search strategies used with paper document versus website.

Strategy	Paper document				Website			
	Tasks ($N = 141$)		Respondents ($N = 28$)		Tasks ($N = 141$)		Respondents ($N = 28$)	
	%	n	%	n	%	n	%	n
Only orienteering	59.6	84*	96.4	27	34.0	48	78.6	22
Only teleporting	31.2	44	75.0	21	52.5	74*	78.6	22
Combination	9.2	13	17.9	5	13.5	19	50.0	14

Note: χ^2 was computed to detect significant differences between the two conditions. Time between studies was 13 months.
*$p < .05$.

the HCWs to use the more efficient teleporting strategy significantly more ($p < .05$).

3.4.3. Comparison of the satisfaction outcomes

Overall, the design, content, and features of the website were received better than those of the paper document. The participants were very satisfied with several aspects of the website. While thinking aloud they verbalized their appreciation of the fact that the information was "conveniently arranged" ($n = 13$), and had an "intelligible design" ($n = 7$).

Participants were also positive about the practical content of the website. Five HCWs labeled the content as "very informative" and five expressed that the tool would be a valuable addition to existing information sources about MRSA:

> I recently looked up 'MRSA' in 'Herold', a book about medicine, and it only contained one sentence about MRSA. But it is also the book people use in medical school. That one sentence is really insufficient. The book only says USA 40% MRSA, the Netherlands 1%. In comparison, I think this website is very good. (Respondent 1 Germany, physician)

The same participant even mentioned that the practical content of the website should "become a standard in the education of each health care worker". The overall usability was perceived as good by the HCWs. Eight of them explicitly stated that the tool was "easy to work with" and six people valued the combination of three different search options.

4. Discussion

The objective of our research was to tailor the communication of expert-driven infection control guidelines to a communication format that better fits HCWs' practical information needs. Our first study revealed that the existing paper-based guidelines hinder their application by HCWs in practice because of usability problems related to poorly structured information, insufficient information quality, and a mismatch between experts' and HCWs' vocabulary. Based on HCWs' information needs, we applied three main design principles of usability to a website: better navigation (the guidelines should be searchable in several ways); multimodality (the guidelines should not be presented as text only), and action-orientation (the guidelines should be presented as HCWs' behaviors). The most obvious outcomes of our study are the outperformance of the website with respect to effectiveness (the number of correctly completed tasks), efficiency (the time needed to complete these tasks), and a higher degree of satisfaction with the website compared with the paper document.

The increased effectiveness and efficiency of the website compared with the paper document seemed to be caused mainly by the inclusion of practical, action-oriented content communicated in HCWs' vocabulary, and by incorporating multimedia examples and different search options, as can be concluded from the number of matching and information quality problems that dropped in the website condition. Remarkably, however, the number of problems related to information structure doubled when HCWs worked with the website. Further inspection of the observation and verbalization data suggests that the participants spent less time navigating to the answer in the web-based environment, but once the relevant information was detected, they needed more time for navigating within and away from the answer. This might be ascribed to the fact that the navigation structure was based on both advanced information retrieval techniques (Tigelaar et al., 2008) and research involving real users (Card Sort, see Verhoeven et al., 2008), in contrast to the standardized answer format, which was based purely on existing usability principles (Koyani et al., 2006).

Other usability issues that were raised during the website evaluation were the slow speed of the pages load times (see Section 3.3.3), the lack of hyperlinks, and the difficulty of moving in and away from web pages (see Section 3.3.1). Also, the number of incomprehensibility problems did not decrease, as we expected. One might question why these issues were not already addressed during website design. A possible explanation is that the design team mainly concentrated on preventing the problems detected by the thinking-aloud tests in study 1. Possibly, the design team's attention for choices that might have easily prevented errors (such as an easily accessible glossary for difficult terms), was thereby distracted.

Overall, our results show that a user-centered website is a suitable mode for communicating infection control guidelines. Compared with the paper document, the website functions better with respect to all three usability components: effectiveness, efficiency, and satisfaction.

4.1. Implications for further research

Our study confirms two major advantages of user-centered design. First, user-centered design yields more efficient and effective means of communication. Second, users develop a sense of ownership for the medium (website), so it can be integrated into the environment more quickly (Abras et al., 2004). Each of these benefits provides implications for further research.

4.1.1. The benefit of more efficient and effective means of communication

Our study demonstrated that user-centered design indeed contributed to the website's efficiency and effectiveness. However, considering the website's effectiveness, it appeared that although more tasks were completed successfully with the website than with the paper document, the number of usability problems did not substantially decrease. A shift could be observed in the type of problems that were encountered: respondents experienced twice as many problems related to information structure when working with the website compared with the paper document. However, the majority of these problems were encountered when the required information had already been retrieved and not so much while HCWs were searching for the answer, as was the case with the paper document. We ascribe this to the fact that the navigation menu was based on information retrieval techniques (Tigelaar et al., 2008) and user-centered design (Card Sort, see Verhoeven et al., 2008), in contrast to the standardized answer format, which was based on existing usability principles with no real users involved (Koyani et al., 2006). Although Card Sorting is a reliable method that provides input for the categorization of information units and generates suggestions for the website navigation menu (Tullis, 2003), it does not tell us how to present the information itself. It seemed that the participating HCWs expressed difficulties with the presentation of infection control guidelines because it differed too much from what they were acquainted with. As HCWs are used to guideline documents concentrating on legislation and regulation, they seem to have problems with a more vivid, multimodal presentation of the information and to navigate within and away from the information. These observations may lead to further (longitudinal) research of the "habituation process" with innovative ways of communication in highly traditional communication cultures such as health care.

Because HCWs had to perform more and different actions (e.g., link-clicking versus page-turning) in order to complete a task in the web-based condition than in the paper-based condition (3.9 versus 3.0 actions) it would be expected that the extraneous cognitive load would also increase, which would lead to longer performance times. However, the website enabled HCWs to complete tasks over 4 min faster than the paper document. Apparently, browsing the website's menu structure required less time than flipping through the document's pages. So the extraneous cognitive load was not so much linked to the objective number of actions HCWs undertook, but to medium-specific characteristics: web-based communication supports simultaneous use of different information units via hyperlinks and also confers the ability to skip unnecessary information. Although HCWs indicated that using the website was much more efficient than the paper document, they did not appear to experience a higher cognitive load when using the website, despite the higher number of performed actions. This finding corresponds with recent work from Holzinger et al. (2009). They showed that despite interactive and dynamic media being cognitively more demanding than static media, use of dynamic media does not negatively affect learning performance because no differences were detected between usage of static and dynamic media to learn.

The low extraneous cognitive load experienced by the HCWs was possibly caused by our attempts to minimize HCWs' extraneous cognitive load when using the website. For example, we visualized procedural information (e.g., hand washing, contact isolation, etc.) in videos, tables, and decision trees, and presented action-oriented steps in list forms. Other research also demonstrated that the efficiency of visual media is often preferred above written or verbal information, because the latter unduly loads the learner with unnecessary information (Clark et al., 2006).

Our study showed that learning with presentation of information in combination with pictures, videos, decision trees, and other visual cues, positively affects elaboration of information (since task performance time significantly decreased in the website condition), which is considered to be most effective for learning. This finding is in line with Mayer's multimedia learning theory (Mayer, 2005). As an efficient format of instructional materials promotes learning (Chandler and Sweller, 1991; Clark et al., 2006), it may be interesting to further develop the website's educational functionalities. The HCWs in our sample already suggested that the existing website should become a standard in each HCW's education. Given the growing importance of the Internet to physician professional development, we anticipate on this by building an e-learning system.

Another functionality lowering HCWs' extraneous cognitive load might be incorporating interactive dialogue functionality into the website. Since users are often unable to express their need for information in a single, self-contained query (Nijland et al., 2008), the dialogue system will allow users to ask for clarification, make corrections to the system's interpretation of utterances, and ask follow-up questions (comparable to the system developed by Chai et al., 2001).

4.1.2. *The benefit of creating a sense of ownership for the means of communication*

The second advantage of user-centered design is that users develop a sense of ownership for the website, so that the website can be integrated into the work environment more quickly (Abras et al., 2004). We realize that commitment to the website among a sample of 28 health care workers is not enough to establish a sense of ownership among all intended users. However, usually when new technologies come about, they are only adopted by a small group of people initially; later, they spread to other people. Diffusion research suggests that a small group of highly respected peers, approximately 10% of all end users, influences the adoption decisions of the other 90% (Rogers, 2003). The HCWs who participated in our study positively valued the website's usability and appreciated the practical relevance of the information (see also Verhoeven et al., 2009). If HCWs advocate the website among their peers, the chances for creating a sense of ownership among other HCWs increase, next to the chances for successful implementation.

Since 19 February 2008 the web-based tool can be accessed via www.mrsa-net.nl (in both Dutch and German) and has been visited by more than 110.000 unique visitors (d.d. 17 June 2009), and now has an average of 450 unique users daily. Although the website has been received relatively well, its implementation in daily clinical practice can still be increased. Therefore, we investigated how adoption of the tool among HCWs can be stimulated by critical success factors that play a role with the diffusion of technologies in health care, such as opinion leaders, communication, training, etc. (Verhoeven et al., 2009). Adoption of the tool is not only determined by the guideline characteristics of form, compatibility, and trialability, but there are also extraneous variables on both the individual (e.g., attitude, knowledge, job satisfaction) and the environmental level (e.g., communication, training, management values) that must be considered when implementing a website such as this one (Green and Kreuter, 2006). Most commonly, these extraneous factors are left out of consideration when implementing innovations in health care (Cain and Mittman, 2002; Kaplan, 1997).

Together, these two benefits advocate the application of user-centered design techniques. In health care, however, the culture is still to train users (HCWs or patients) to adapt to poorly designed documents, rather than to design the document to fit the target group's tacit knowledge (Johnson et al, 2005). Based on our findings, we recommend the involvement of HCWs in the design process of guidelines to externalize their tacit knowledge, which has been advocated before (Gross et al., 2001; McCoy et al, 2001; Murphy, 2002; Van Gemert-Pijnen et al., 2005). However, as far as we know, we were the first to actually take action within this field.

The tendency to focus on expert-oriented criteria is also visible in the field of web-design. Numerous criteria have been developed to guarantee quality of health-related websites that tend to reflect professional concerns, including accuracy, completeness, readability, disclosures, and references (Provost et al., 2006). By contrast, little is known about the user perspective on health websites, although we know that users and experts generate different criteria for assessing the quality of traditional non-web-based information materials (Coulter et al., 1998). Our study serves as paramount evidence of the discrepancy between expert- and user-oriented criteria and demonstrates the usefulness of integrating users' tacit knowledge into system criteria, ultimately suggesting that user-centered design methods should be employed.

4.2. *Implications for infection control practice*

Our results suggest that three design principles are important in order to realize a usable website with infection control guidelines:

1. The addition of key questions (and their answers) that arose during the first study and the use of terminology that matches the vocabulary of the users;

2. Presentation of the information in a multimodal fashion; and
3. Enabling users to apply a combination of search strategies.

However, HCWs' needs regarding the communication of infection control guidelines are context-specific and therefore, our design principles are not universal. Experts who are responsible for guideline communication need to involve target users in the development process, such as employing thinking-aloud research methods, to determine the exact needs of their intended users. Furthermore, based on our findings we suggest that when developing infection control guideline communication, experts should consider:

1. How to optimally present the guideline content in such a way that both safety regulations/legislation and practical information are optimally integrated;
2. Develop the most efficient communication format possible in order to lower HCWs' extraneous cognitive load. HCWs will abandon modes of communication demanding a high cognitive load, as workload in the health care setting is already high; and
3. Consider external factors when implementing the new guideline communication.

4.3. Limitations

The major limitation of this study, which is general to all task-oriented studies, is that we did not measure HCWs' actual behavior. HCWs may answer questions in this type of studies in a way that they think is socially desirable, or "right", rather than the way in which they actually practice. However, the available evidence supports the validity of task-oriented studies for measuring differences between groups (Carey and Garett, 1996).

Our study approach concentrates on the ability of HCWs to perform tasks with infection control guidelines. This task-oriented approach contrasts with the "system-oriented" approach in which the quantity of relevant documents retrieved are focus of attention. Measures like recall and precision are used. Although these measures ignore the user and do not capture the interactive nature of the actual use of systems, they are useful in measuring retrieval system performance (Hersch et al., 2002). Therefore, we also investigated the website's system performance, which has been reported elsewhere (Tigelaar et al., 2008).

Although qualitative methods enabled us to optimally explore the user perspective, we could have benefited from quantitative techniques. The type of usability testing we used is probably the most expensive and time-consuming of the available methods. Numerous other approaches are discussed in the evaluation literature. These include cost–benefit analyses, document analysis, and surveys (Kaplan, 1997). For instance, several validated instruments are available to measure user satisfaction. However, questionnaires can only confirm known and assess their scores (Van Velsen et al., 2008). This further legitimates our choice for a qualitative approach that enabled us to identify problems we would not have found by using quantitative research.

5. Conclusion

This paper provided insight in the added value of usability engineering for the development of websites in the health care domain. Our research demonstrated that investigating the way end users work with a medium resulted in an improved communication means that enables them to retrieve relevant information more efficiently, effectively, and with higher satisfaction. This paper provides the steps for dynamically communicating clinical practice guidelines and positively affecting elaboration of information, which is considered to be most effective for learning. Furthermore, the paper shows how to undertake usability testing in order to elicit user input for usability improvement of existing communication means.

Acknowledgements

This study was financially supported within the EUREGIOMRSA-net Twente/Münsterland under the European Regional Development Fund (ERDF) funded by the European Union within the Community Initiative INTERREG-IIIA (2-EUR-V-1 = 96) as well as by the Ministry of Economics from the German state of Nordrhein-Westfalen. Furthermore, the authors thank Almer Tigelaar, M.Sc., Rieks op den Akker, Ph.D., and Langdradig Internet Solutions for their contribution to the website development.

References

Abras, C., Maloney-Krichmar, D., Preece, J., 2004. User-centered design. In: Bainbridge, W. (Ed.), Encyclopedia of Human–Computer Interaction. Sage Publications, Thousand Oaks.

AGREE Collaboration, 2003. Development and validation of an international appraisal instrument for assessing the quality of clinical practice guidelines: the AGREE project. Quality Safety Health Care 12, 18–23.

Bennett, N.L., Casebeer, L.L., Kristofco, R.E., Strasser, S.M., 2004. Physicians' internet information-seeking behaviors. Journal of Continuing Education in the Health Professions 24, 31–38.

Berhe, M., Edmond, M.B., Mearman, G.M., 2005. Practices and an assessment of health care workers' perceptions of compliance with infection control knowledge of nosociomal infections. American Journal of Infection Control 33, 55–57.

Boren, M., Ramey, J., 2000. Thinking aloud: reconciling theory and practice. IEEE Transactions on Professional Communication 43, 261–278.

Cain, M., Mittman, R., 2002. Diffusion of innovation in health care. California Health Care foundation, Oakland.

Carey, T.S., Garett, J., 1996. Patterns of ordering diagnostic tests for patients with acute low back pain. Annals of Internal Medicine 10, 807–814.

Chai, J., Budzikowska, M., Horvath, V., Nicolov, N., Kambhatla, N., Zadrozny, W., 2001. Natural language sales assistant—a web-based

dialog system for online sales. In: Proceedings of the Thirteenth Innovative Application of Artificial Intelligence Conference. AAAI Press, Seattle, pp. 19–26.

Chandler, P., Sweller, J., 1991. Cognitive load theory and the format of instruction. Cognition and Instruction 8, 293–332.

Clark, R., Nguyen, F., Sweller, J., 2006. Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load. Pfeiffer, San Francisco.

Committee for Hospital Hygiene and Infection Prevention at the Robert Koch Institute, 1999. Empfehlung zur Prävention und Kontrolle von Methicillin-resistenten *Staphylococcus aureus* (MRSA) in Krankenhäusern und anderen medizinischen Einrichtungen. (Recommendation for Prevention and control of Methicillin-resistant *Staphylococcus aureus* (MRSA) in hospitals. Bundesgesundheitsblatt 42, 954–958.

Coulter, A., Entwistle, V., Gilbert, D., 1998. Informing Patients: An Assessment of the Quality of Patient Information Materials. King's Fund Publishing, London.

De Jong, M., Lentz, L., 2006. Scenario evaluation of municipal websites: development and use of an expert-focused evaluation tool. Government Information Quarterly 23, 191–206.

Dutch Working Party on Infection Prevention, 2005. MRSA—General, Hospitals. Leiden.

Ericsson, K., Simon, H., 1980. Verbal reports as data. Psychological review 87, 215–251.

Ericsson, K., Simon, H., 1993. Protocol Analysis: Verbal Reports as Data. MIT Press, Cambridge.

Fervers, B., Burgers, J.S., Haugh, M.C., Brouwers, M., Browman, G., Cluzeau, F., Philip, T., 2005. Predictors of high quality clinical practice guidelines: examples in oncology. International Journal for Quality in Health Care 17, 123–132.

Friedrich, A.W., Daniels-Haardt, I., Köck, R., Verhoeven, F., Mellmann, A., Harmsen, D., Gemert-Pijnen, J.E.W.C., van Becker, K., Hendrix, M.G.R., 2008. EUREGIO MRSA-net Twente/Münsterland—a Dutch–German cross-border network for the prevention and control of infections caused by Methicillin-resistant *Staphylococcus aureus*. Eurosurveillance 35, 1–11.

Frøkjær, E., Hertzum, M., Hornbæk, K., 2000. Measuring usability: are effectiveness, efficiency, and satisfaction really correlated? In: Proceedings of ACM Conference on Human Factors in Computer Systems. ACM Press, New York, pp. 345–352.

Gould, J.D., Lewis, C., 1985. Designing for usability: key principles and what designers think. Communications of the ACM 28, 300–311.

Green, L.W., Kreuter, M.W., 2006. Health promotion planning; an educational and environmental approach. Mayfield Publishing Co., Palo Alto.

Gross, R., Greenfield, S., Cretin, S., Ferguson, J., Grimshaw, Grol., R., 2001. Optimal methods for guideline implementation. Medical Care 39 (S2), 85–92.

Hersch, W.,R., Crabtree, K., Hickam, D.H., Sacherek, L., Friedman, C.P., Tidmarsh, P., Mosbaek, C., Kraemer, D., 2002. Factors associated with success in searching MEDLINE and applying evidence to answer clinical questions. Journal of the American Medical Informatics Association 9, 283–293.

Holzinger, A., 2005. Usability engineering for software developers. Communications of the ACM 48, 71–74.

Holzinger, A., Kickmeier-Rust, M., Wassertheurer, S., Hessinger, M., 2009. Learning performance with interactive simulations in medical education: lessons learned from results of learning complex physiological models with the HAEMOdynamics SIMulator. Computers & Education 52, 292–301.

Hom, J., 1998. The Usability Methods Toolbox. San José State University, San José, 1998. URL: http://jthom.best.vwh.net/usability/ [accessed: 18 June 2009].

Hornbæk, K., 2006. Current practice in measuring usability: challenges to usability studies and research. International Journal of Human–Computer Studies 64, 79–102.

International Organisation for Standardization, 1998. Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)—Part 11: Guidance on Usability—Part 11: Guidance on Usability (ISO 9241-11:1998).

Jaspers, M.W.M., 2009. A comparison of usability methods for testing interactive health technologies: methodological aspects and empirical evidence. International Journal of Medical Informatics 78, 340–353.

Johnson, C.M., Johnson, T.R., Zhang, J., 2005. A user-centered framework for redesigning health care interfaces. Journal of Biomedical Informatics 38, 75–87.

Kaplan, B., 1997. Addressing organizational issues into the evaluation of medical systems. Journal of the American Medical Informatics Association 4, 94–101.

Kinzie, M., Cohn, W., Julian, M., Knaus, W.A., 2002. A user-centered model of website design: needs assessment, user interface design and rapid prototyping. Journal of the American Medical Informatics Association 9, 320–330.

Krahmer, E., Ummelen, N., 2004. Thinking about thinking aloud: a comparison of two verbal protocols for usability testing. IEEE Transactions on Professional Communication 47, 105–117.

Koyani, S.J., Bailey, R.W., Nall, J.R., 2006. Research-based Web Design & Usability Guidelines. US Government Printing Office, Washington, DC.

Landis, J.R., Koch, G.G., 1977. The measurement of observer agreement for categorical data. Biometrics 33, 159–174.

Loorbach, N., Karreman, J., Steehouder, M., 2007. Adding motivational elements to an instruction manual for seniors: effects on usability and motivation. Technical Communication 54, 343–358.

Marchionini, G., 1995. Information Seeking in Electronic Environments. Cambridge University Press, New York.

Mayer, R.E. (Ed.), 2005. The Cambridge Handbook of Multimedia Learning. Cambridge University Press, Cambridge.

McCoy, K.D., Beekmann, S.E., Ferguson, K.J., Vaughn, T.E., Torner, J.C., Woolson, R.F., Doebbeling, B.N., 2001. Monitoring adherence to standard precautions. American Journal of Infection Control 29, 24–31.

Murphy, D.M., 2002. From expert data collectors to interventionists: changing the focus for infection control professionals. American Journal of Infection Control 30, 120–132.

Muto, C.A., Jernigan, J.A., Ostrowsky, B.E., Richet, H.M., Jarvis, W.R., Boyce, J.M., 2003. SHEA guidelines for preventing nosocomial transmission of multidrug-resistant strains of *Staphylococcus aureus* and *Enterococcus*. Infection Control and Hospital Epidemiology 24, 362–386.

Nielsen, J., 1993. Usability Engineering. Morgan Kaufmann, San Francisco.

Nijland, N., Van Gemert-Pijnen, J.E.W.C., Boer, H., Steehouder, M.F., Seydel, E.R., 2008. Evaluation of Internet-based technology for supporting self-care: problems encountered by patients and caregivers when using self-care applications. Journal of Medical Internet Research 10, e13.

Patton, M.W., 1990. Qualitative Evaluation and Research Methods. Sage Publications, Newbury Park.

Pittet, D., Donaldson, L., 2006. Challenging the world: patient safety and health care-associated infection. International Journal for Quality in Health Care 1, 4–8.

Pollock, E., Chandler, P., Sweller, J., 2002. Assimilating complex information. Learning and Instruction 12, 61–86.

Provost, M., Koopalum, D., Dong, D., Martin, B.C., 2006. The initial development of the WebMedQualScale: domain assessment of the construct of quality of health web sites. International Journal of Medical Informatics 75, 42–57.

Rogers, E.M., 2003. Diffusion of Innovations. Free Press, New York.

Saillour-Glenisson, F., Michel, P., 2003. Individual and collective facilitators of and barriers to the use of clinical practice guidelines by physicians: a literature review. Revue d Epidemiologie et de Sante Publique 51, 65–80.

Sachs, M., 2006. Successful strategies and methods of nursing standards implementation. Pflege 19, 33–44.

Shekelle, P.G., Kravitz, R.L., Beart, J., Marger, M., Wang, M., Lee, M., 2000. Are nonspecific practice guidelines potentially harmful? A randomized comparison of the effect of nonspecific versus specific guidelines on physician decision making. BMC Health Services Research 34, 1429–1448.

Teevan, J., Alvarado, C., Ackerman, M.S., Karger, D.R., 2004. The perfect search engine is not enough: a study of orienteering behavior in directed search. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM Press, New York, pp. 415–422.

Thomas, C., Bevan, N. (Eds.), 1996. Usability Context Analysis: A Practical Guide. National Physical Laboratory, Teddington.

Tigelaar, A., Op den Akker, R., Verhoeven, F., 2008. Matching queries to frequently asked questions: search functionality for the MRSA Web-Portal. In: Paper submitted to the Ninth Dutch–Belgian Information Retrieval Workshop. University of Twente, Enschede.

Tullis, T.S., 2003. Using card-sorting techniques to organize your intranet. Intranet Journal of Strategy & Management 1, 1–9.

Van den Haak, M.J., 2008. A penny for your thoughts—investigating the validity and reliability of think-aloud protocols for usability testing. Ph.D. Dissertation, University of Twente, Enschede.

Van Gemert-Pijnen, J.E.W.C., 2003. The development and functioning of infection prevention protocols. A study of communication driven by legislation and regulations. Ph.D. Dissertation, University of Twente, Enschede.

Van Gemert-Pijnen, J.E.W.C., Hendrix, M.G.R., Van der Palen, J., Schellens, P.J., 2005. Performance of methicillin-resistant *Staphylococcus aureus* protocols in Dutch hospitals. American Journal of Infection Control 33, 377–384.

Van Velsen, L., Van der Geest, T., Klaasen, R., Steehouder, M., 2008. User-centered evaluation of adaptive and adaptable systems: a literature review. The Knowledge Engineering Review 23, 261–281.

Verhoeven, F., Gemert-Pijnen, J.E.W.C., van Friedrich, A.W., Daniels-Haardt, I., Hendrix, M.G.R., 2007. Euregionale MRSA-preventie en bestrijding: een vergelijking van Duitse en Nederlandse richtlijnen. [Euregional MRSA-prevention and control: a comparison of Dutch and German guidelines]. Infectieziekten Bulletin 4, 125–129 (in Dutch).

Verhoeven, F., Van Gemert-Pijnen, J.E.W.C., Friedrich, A.W., Daniels-Haardt, I., Hendrix, M.G.R., Steehouder, M., 2008. The development of a web-based information tool for cross-border prevention and control of Methicillin Resistant *Staphylococcus aureus*. International Journal of Infection Control 4, 1–11.

Verhoeven, F., Steehouder, M.F., Hendrix, R.M.G., Van Gemert-Pijnen, J.E.W.C., 2009. Factors affecting health care workers' adoption of a website with infection control guidelines. International Journal of Medical Informatics, in press, doi:10.1016/j.ijmedinf.2009.06.001.

Yu, H., Lee, M., Kaufman, D., Ely, J., Osheroff, J.A., Hripscsak, G., Cimino, J., 2007. Development, implementation, and a cognitive evaluation of a definitional question answering system for physicians. Journal of Biomedical Informatics 40, 236–251.