Discount User-Centered e-Health Design: A Quick-but-not-Dirty Method

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Abstract. The philosophy of discount usability engineering perfectly fits the health care setting, where cost-cutting is ubiquitously present. We adapted Nielsen's discount usability approach for the health care setting by combining traditional thinking aloud (n=18) and Card Sorting (n=18) with online prototyping (n=5) and simplified thinking aloud (n=5). We used the approach to design an efficient and effective website with infection control guidelines for nursing home staff leading to high levels of satisfaction within a time frame of three months for the total cost of €7195. Based on our experiences, we would advocate using this discount user-centered approach for the design of e-health applications. Future research should concentrate on integrating the principles of creative co-design methods and online research into the discount usability approach.

Keywords: Discount usability engineering; user-centered design; usability testing; health care; infectious diseases; thinking aloud; Card Sorting; prototyping.

1 Introduction

1.1 Web-Based Infection Control Guidelines

Health care-associated infections cause thousands of preventable deaths each year in several types of care settings, including nursing homes [1]. Therefore, it is crucial that nursing home staff adhere to infection control guidelines. Although most nursing home staff are aware of the rationale for infection control practices, adherence is generally poor [2].

In addition to contextual reasons such as negative management values and a high workload, the insufficient tailoring of infection control guidelines as a communication means to nursing home staff needs might account for low adherence rates. Previous research has demonstrated that health care workers repeatedly encounter problem with the usability of the guidelines, which could be detrimental to their uptake in clinical practice [3-5]. The problem with infection control guidelines as a communication means is that they are rather expert-driven. Expert-driven guideline communication can be characterized by a strong focus on scientific validation, regulation, and legislation [6]. In the design process, higher priority is given to a consensus on content-related issues among experts than to nursing home workers' practical information needs. This can make the document difficult for individual nursing home workers to use as a resource and to identify procedures for daily work practice [7].

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A possible solution to enhance the usability of the expert-driven guideline format is to communicate the traditional, paper-based guidelines in a format that better fits the practical information needs of the nursing home staff. 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' readability [8].

1.2 User Involvement in the Design Process

The development of a website allows the direct involvement of nursing home staff, which can lead to a higher level of usability. In a user-centered design process, nursing home workers can 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 [4, 7]. 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 [9].

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 [10-12]. 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 [10]. 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.

Since it is often thought that experts are not able to identify real user problems [13], and problems with the quality of guideline communication are particularly caused by their expert-driven character, it is better to perform usability testing rather than usability inspection when improving the format of infection control guidelines. With this in mind, design of web-based guideline communication should incorporate the tools and methods applied in user-centered design: requirements gathering, analysis, design, implementation, testing, and deployment [14]. Previous studies have shown the benefits of involving users via usability testing in the design process of e-health applications [3-5]: First, user input can be taken into account before the application's release so the application's content, structure, and lay-out are completely tailored to the user needs. This leads to a high level of satisfaction among users. Second, early analysis and modeling of the mental processes involved in users' activity helps prevent failures and future costs [14, 15]. Third, it may be that user's involvement in the design process creates ownership, fosters applicability of the application, and leads to a willingness to integrate the application into daily routine [7].

Approaches based on usability engineering recently have been introduced into medical informatics [16, 17]. However, usability testing that follows a stringent approach is expensive, even if what a "modest" usability lab is constructed and staffed. The cost of using these techniques might be one important reason for the fact that usability testing is not used as a standard in medical informatics [18]. Or rather, the reason is the *perceived* cost of using these techniques, as it has been shown that many usability techniques can be deployed quite cheaply [19].

1.3 Discount Usability Engineering as a Premise

A method that is increasingly becoming popular to overcome the aforementioned problems related to time- and cost investments is "discount usability engineering". Discount usability engineering is a phrase popularized by Jakob Nielsen [19], a long-time proponent of smaller, cheaper usability studies for projects with small budgets for usability. Discount usability engineering is originally based on the use of the following three techniques: prototypes, simplified thinking aloud, and heuristic evaluation. The premise for this approach is that it is simple and has more a chance of being employed in practical situations [14]. The approach utilizes a small number of users who are tested and statistical analysis cannot be applied [20]. Usability testing is not intended to be a research experiment from which we induce a generalizable conclusion. According to Dumas and Redish, a research study seeks to know "whether or not some phenomenon exists", while a usability test aims "to uncover problems" and thereby improve an application's design [21]. Rather, the findings are qualitative in nature [22]. The methods are quick, and if one is not developing an aircraft cockpit interface with lives at stake, the risk of not finding every last usability problem is not serious [20].

Formal usability engineering can be costly to any project budget but by employing discount usability engineering, a cost effective method which provides clear identification of problems is applied. It is simple in design, and in the real world, stands a better chance of being applied and reaping the rewards towards an improved product 19]. Multiple variations of the discount usability engineering approach could be identified in the literature, with costs ranging from 62000 dollar [19] to almost nothing [16], and time spans varying between a year [19] to one day [23] or even 30 minutes [24]. The philosophy of discount usability engineering perfectly fits the health care setting, in which budgets are restrained and cost-cutting is ubiquitously present.

1.4 Discount Usability Engineering for the Design of New (e-Health) Applications

Although usability testing and inspection are steadily gaining ground in the health care setting [16], only few papers could be identified that focused on discount usability engineering in a context of medical informatics. Beuscart-Zéphir et al [15] adapted discount usability engineering to support the choice between several prototypes of a clinical information system. Discount usability engineering was used by Kaplan and colleagues [16] to evaluate a prototype of a computer-based clinical case intended for educational purposes. Yao and Gorman applied the method for the redesign of a web-based clinical library [14]. In all these studies, discount usability engineering was employed for the evaluation of existing systems or system prototypes. In here, the question rises whether the discount approach also holds for the design of new applications, as in our case a website with infection control guidelines for the nursing home setting. In other words: Are the available, existing discount usability methods suitable for the design and development of new technological applications, or do other research methods have to be incorporated? This paper is focused around this question.

1.5 Objectives

With this study, we aim to identify a discount approach for user-centered design of a completely new e-health application (without a prototype being available). We tried to achieve this by employing efficient and effective methods for both planning, administering, and analyzing the study within a time frame of three months, for cost lower than 7500€, including the design, implementation, and evaluation of the application.

We intend to demonstrate that although our method is quick, it definitely is not dirty, since our methodology is based on scientific design principles and still enables data analysis at an academic level. The user-centered design process of a website with infection control guidelines in a nursing home setting served as a casus.

2 Methods

2.1 Research Context

The "Health care Foundation Marga Klompé" is a coordinating organization that facilitates both domiciliary care as well as nursing home care. The organization comprises 23 nursing homes, scattered over six cities in the East of the Netherlands, and employs approximately 1750 people. The organization together hosts 1100 intramural clients, 110 transmural clients, and yearly offers 80000 hours of domiciliary care (extramural). The organization hires an infection control nurse from the hospital for 16 hours weekly. One of the core tasks of the infection control nurse is to write and implement the infection control guidelines [25]. The purpose of infection control guidelines is to educate HCWs about the direction on the prevention and control of infectious diseases and uphold standards of safe work practice.

In the last few years, Marga Klompé's infection control nurse observed low adherence rates to the guidelines and wondered whether the quality of the documentation contributed to this. She therefore intended to replace the paper-based guidelines with a website in order to overcome the usability problems experienced with the paper-based guidelines. In order to do so, she called in the help of a behavioral scientist (FV). Considering the restricted budget in time and money, the infection control nurse and the behavioral scientist agreed to apply the principles of discount usability engineering.

The research project concerns the development, implementation, and evaluation of a website with infection control guidelines. The users concerned by the project are all physicians, nurses, and assistant-nurses within the organization.

2.2 Methods

"Discount usability engineering" is a method based on the use of the following three techniques [19]:

1. Prototypes (referred to by Nielsen as scenarios): Prototypes are essentially a simple version of a system, such as paper mock-ups. This technique saves costs on system development by delaying development until the majority of testing is complete.

2. Simplified thinking aloud: Test users think aloud as they attempt to complete tasks while observer takes notes. The method provides insight into users' thoughts as they use an interface. Also, this method saves costs on equipment since it does not require videotaping or even a lab and does not require recruiting or accommodating large numbers of people.
3. Heuristic evaluation: A method of inspecting a system's usability that supplements user testing. A small number of evaluator examine the interface and assess whether it complies with usability principles or heuristics, such as "consistency and standards", "aesthetic and minimalistic design", and "recognition rather than recall".

We did not choose however to blindly copy Nielsen's usability engineering method. We assume there is not one "golden standard" to conduct user-centered e-health design, for two reasons.

First, the specific context of each case requires a careful consideration of the available research methods, time and time again. Particularly in the health care setting, the context in which the system is used is inherently tied to the application [26]. In our case, we believed that solely employing simplified usability methods would not serve the purpose of developing a website with infection control guidelines for nursing homes. Since no prototype was available, we preferred to start with a more traditional, ethnographic thinking aloud method in order to identify problems encountered with the current, paper-based infection control guidelines. The results were used as input to build the mock-up prototypes, and from there on, standard discount methods could be applied: prototypes and simplified thinking aloud.

Second, although heuristic evaluation is one of Nielsen's discount usability methods, we did not apply this method of usability inspection. Since it is often thought that experts are not able to identify real user problems [13], and problems with the quality of guideline communication are particularly caused by their expert-driven character, we perceived it better to perform usability testing rather than usability inspection when improving the format of infection control guidelines. Besides, while usability heuristics are useful, they are not applied by rote, and they can require interpretation. Heuristics are not uniformly interpretable, and this causes competing forces [27].

In short, for the case of this study, we adapted Nielsen's discount usability approach because (1) it is less appropriate for the design of *new* applications and (2) heuristic expert evaluation will not play its full right given the fact that in our case, the expert-driven character of the existing guidelines is the major cause of usability problems. Therefore, we complemented Nielsen's method with traditional thinking aloud to make it suitable for *new* applications, and replaced the heuristic evaluation with a more user-centered method: Card Sorting. Together, the methods generated the optimal content, structure, and lay-out of the website. Each of our selected methods will be elaborated on below.

Traditional thinking aloud (content). Of all usability testing methods, thinking aloud has been most often used in the health care domain [29]. 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 [10, 12]. At the beginning of a design process, traditional thinking aloud methods work better than simplified thinking aloud, since traditional

thinking aloud aims to uncover and articulate existing work practices [26]. In the beginning of our research, no single user need was known to the researcher and in order to gain a broad a possible vision of the nursing home staff's needs and problems they encountered with using existing control guidelines, no restrictions on administration and analysis of the thinking aloud data were imposed. Therefore, we started our research with 18 traditional thinking aloud sessions to identify the usability problems that occurred with the paper-based guidelines, so input for the website could be generated.

Card Sorting (structure). Card Sorting is often applied as a user-centered method for designing the information structure of a website [29]. The process involves respondents sorting a series of cards, each labeled with a piece of content or functionality, into groups that make sense to respondents. Card Sorting can provide insight into users' mental models, illuminating the way that they often tacitly group, sort and label tasks and content within their own heads. Those patterns are often referred to as the users' mental model. By understanding the users' mental model, we can increase findability, which in turn makes the product easier to use. We applied the principle of Open Card Sorting since this is useful as input to information structures in new or existing sites and products [30]. Respondents were given cards showing site content with no pre-established groupings. They were asked to sort cards into groups that they felt are appropriate and then describe each group.

Prototyping (lay-out). A prototype is a draft version of a website. Prototypes allow the exploration of ideas among users before investing time and money into development. It is much cheaper to change a product early in the development process than to make changes after the application has been developed. A prototype can be anything from paper drawings (low-fidelity), click-through of a few images or pages, or a fully functioning website (high-fidelity). There is an on-going debate in the literature about using low- versus high-fidelity prototyping [31]. Opinions vary a great deal about how much a prototype should resemble the final version of the design. In theory, low-fidelity sketches are quicker to create. An advantage is that using rough sketches users may have an easier time suggesting changes. High-fidelity prototypes take the users as close as possible to a true representation of the user interface. We tried to stroke the golden mean by opting for "medium-fidelity" prototypes: two different homepage mock-ups were created and sent by e-mail to intended users, who provided their comments via e-mail.

Simplified thinking aloud (synergizing content, structure, and lay-out). Once the content, structure, and lay-out are fixed, the first functional prototype could be built. We used Nielsen's simplified thinking aloud technique used to 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 [32]. With this approach users were prompted to speak out loud their thoughts about what they are doing and expecting as they are evaluate a piece of software. Users are in a unique position to provide early, authentic feedback. They know what they need and want and can respond to the design. All relevant topics that were raised during the simplified thinking aloud were solved before the website was officially launched online.

2.3 Subjects

A limited number of subjects is one of the showpieces of discount usability engineering. In terms of feasibility, discount engineering requires only three to six users to identify prominent problems. Nielsen and Landauer demonstrated that the benefits from user testing are much larger than the costs, no matter how many subjects are used [33]. Based on mathematical modeling, they showed that the maximum benefit-cost ratio is achieved when using between three and five subjects. With this number of test users, approximately 75% of a system's or website's usability problems for a target user group can be detected.

A random sample involving nursing home staff from different types of wards and with varying occupations (physicians, nurses, assistant-nurses) was selected by the infection control nurse. Respondents were recruited on a voluntary basis. Eligible nursing home staff were at least 18 years old and Dutch-speaking. All respondents were staff at one of the nursing homes of the Marga Klompé Institution in the East Netherlands. They did not need to have prior knowledge or experience with the use of either paper- or web-based infection control guidelines. The numbers of respondents included in each research phase are presented in Table 1. We used different users in each study to avoid any learning effects.

For the traditional thinking aloud, we maintained the mathematical of Nielsen and Landauer to determine the number of respondents. Since our goal was to detect as many usability problems experienced with the use of the existing, paper-based guidelines, we included 18 respondents in order to find 99% of problems [33]. For the prototyping and the simplified thinking aloud, we included five users, as suggested by Nielsen and Landauer.

Table 1. Numbers and types of respondents for each of the research methods

Method	Number per occupational group	Total
Traditional thinking aloud	4 nursing assistants 8 nurses 4 physicians 2 infection control nurses	18
Card Sorting	4 nursing assistants 8 nurses 4 physicians 2 infection control nurses	18
Prototyping	1 nursing assistant 2 nurses 1 physician 1 infection control nurse	5
Simplified thinking aloud	1 nursing assistant 2 nurses 1 physician 1 infection control nurse	5

2.4 Procedure and Materials

The complete design process, including conducting and processing the study and creating and implementing the website, took place between May and July 2009.

Traditional thinking aloud and Card Sorting were combined in one session**.** This implied the 18 respondents were confronted with the two methods subsequently. Respondents were advised to allow 1.5 hour per test session. The tests were conducted in a quiet room somewhere in the nursing home in which the respondent was employed, under the control of a researcher that was equipped with the paper-based infection control guidelines, the interview scheme, and the materials for the Card Sorting method (cards, paper clips, Post-Its, pencil, envelope). Upon arrival for the test sessions, respondents were greeted and thanked for their participation. The respondents were then given an overview of the tasks and expectations during the session. Thinking aloud instructions were provided. The tasks consisted of what if-tasks. A total of 19 different tasks were formulated, each representing on one the chapters in the paper-based guideline document. An example is: "*You read a patient's temperature and wonder what to do with the thermometer. Using the guidelines, can you say aloud which preventive measures you must take?"* The tasks were created in consultation with an infection control nurse who ensured that the tasks represented questions from daily clinical practice. The simulated tasks were adapted for the three categories of respondents: nursing assistants, nurses, and physicians (geriatrists). During the sessions of 45 minutes, respondents described what they were doing and explained it while doing it, sometimes volunteering information and sometimes in response to questions the evaluator asked. No time limit was imposed on the respondents to work on a task, implying that respondents performed as much tasks as they could during 45 minutes. Key literature on usability evaluation suggests that spending roughly 45 minutes per test subject is sufficient to gain an overall idea about the usability [34, 35]. The researcher used a Philips digital voicetracer 660 to record the respondents' verbalizations.

After 45 minutes of thinking aloud, the Card Sorting started. The infection control nurse selected 59 major themes that represented the comprehensive content of the existing guidelines. Each theme, for instance: "*The risks of using chlorine solution for surface disinfection"*, was written on a separate card. The cards were uniquely numbered on the back. Before handing the cards to the respondent, we shuffled the cards and placed them in a pile on a large empty table in front of the respondent. We then asked the respondent to sort the cards into piles according to similarity. We encouraged them not to produce piles that were too small or too large as they perceived it, but we asked that they not aim for a specific number of cards in each pile. After a user had sorted the cards into piles, we asked the respondent to invent a name for each group. They wrote this name of a Post-It note and place it on the group of cards. The respondents typically finished the Card Sorting in about 30 minutes. When finishing the Card Sorting, respondents were given the opportunity to provide additional comments regarding the website and after 90 minutes, respondents were thanked again for their participation. No problems occurred during each of the 18 sessions.

Prototyping: In the next phase, five respondents were approached by e-mail and were required to answer several questions regarding the grading of two mock-up prototypes (see Figures 1 and 2) that the designer developed based on the results from the traditional thinking aloud and Card Sorting. The two mock-ups of the website's homepage were attached to the e-mail. In the e-mail itself, respondents were kindly requested to look at the mock-ups attentively and answer a set of identical questions for each of the prototypes. Questions concerned their first impression of each prototype, their opinion according to prototype's structure, use of color, depiction of images and text, font, etc.,

three positive and three negative aspects of the prototype, and suggestions for improvement. The survey ended by asking respondents to indicate their preference for prototype 1 or 2. Respondents mentioned that it took them no longer than 15 minutes to complete the survey. Many developers and designers use good old pen and paper to conduct prototyping, but we decided to conduct this part of the study online since this saved time and it obliged respondents to formulate clear and concise answers. A qualitative analysis of the answers was conducted to help decide between prototype 1 and 2.

Simplified thinking aloud: In order to "test run" the first functional prototype of the website, we employed direct user testing where we observed five respondents during a 30 minute test. In the test, users were asked to complete a series of the same tasks as were used in the traditional thinking aloud sessions. The procedure was identical to the traditional thinking aloud, with the only difference that respondents this time used the website to complete tasks and the verbalizations were not recorded with a voice recorder, since data analysis could be done based on the researcher's notes instead of by data transcription. We verified whether the problems that occurred with the paper-based guidelines were prevented with the web-based guidelines.

2.5 Analysis

A major difference between traditional user-centered design methods and discount engineering concerns data analysis: Data analysis can for instance be done based on the researcher's notes instead of by data transcription [23]. Because we wanted the website to prevent as much usability problems as possible, we recorded and transcribed data of the traditional thinking aloud data. Once the functional prototype was developed, data transcription was not necessary for the mock-up prototyping and the simplified thinking aloud, since the aim was no longer perfection, but to find recommendations for improvement [19].

Thinking aloud: Data collected included time it took for users to complete the task, whether they completed the task successfully or not, and comments voiced during and after task completion. Data were analyzed using deductive analysis, implying that the coding categories were derived from a conceptual framework developed earlier for the identification of usability problems with infection control guidelines [4].

Card Sorting: Hand sorted card data were entered into WebSortTM tool, and analyzed with IBM's EZ sort application [36], which visualizes the differences and similarities between items in a tree-diagram based on cluster analysis, providing the website's optimal navigation structure. Besides, a qualitative analysis of the labels and the interviews was conducted to assign names to the categories. Cluster analysis provides a level of rigor to the approach, which removes unconscious biases by providing an objective tool for analysis, brings order to what is potentially an unwieldy process, and lends credibility to the results and thus fosters acceptance of them [30].

Mock up prototyping: Comments provided through e-mail by the respondents were categorized into usability issues by the researcher. The comments were reduced to a series of comments that indicated: like or dislike for aspects of the website, suggestions for site improvements and confusion about the site. The researcher grouped comments into these categories and compared the issues among prototype 1 and 2.

The prototype with the fewest comments was selected. The constructive feedback given by the respondents was processed into the functional prototype of the website.

Simplified thinking aloud: Nielsen describes the main difference between simplified and traditional thinking aloud as follows: In simplified thinking aloud, analysis is based on the observer's notes instead of on transcribed verbalized data [12]. The researcher used standard approaches for qualitative data. She took detailed notes during the sessions. Notes included navigational choices each respondent made as he or she worked through the tasks, his or her comments while thinking aloud, responses to the questions the researcher asked, times when actions occurred, and remarks made during debriefing sessions. The notes were translated into practical design recommendations that the designer processed before the website's final launch.

2.6 Time and Cost Investments

Table 2 shows the time span, man-hours and cost in Euros for both the research and design process. From Table 2 can be derived that both the usability testing and the website engineering were realized within a time frame of three months for the total cost of €7195.

Table 2. Time, effort, and cost of various phases of the user-centered e-health design process

Activity	Time span (2010)	Hours	Cost in Euros
• Development of research instruments (traditional thinking aloud, Card Sorting, prototyping, simplified thinking aloud)	May 1st- May 10th	10 [1]	175
• Conducting traditional thinking aloud and Card Sorting	May 10th- May 20th	27 [1]	472.50
• Transcribing thinking aloud data	May 20th- May 30th	54 [1]	945
• Coding of thinking aloud data	June 1st- June 7th	40 [1]	700
• Processing hand-sorted Card Sorting data into WebSort™ software and cluster analysis	June 1st- June 7th	5 [1]	87.50
• Translating thinking aloud data into design recommendations for website lay-out	June 8th	5 [1]	87.50
• Creation of two mock-up prototypes	June 8th- June 10th	10 [2]	600
• Conducting prototyping by e-mail	June 10h- June 15th	1 [1]	17.50
• Analyzing prototyping results	June 16th	3 [1]	52.5
• Creating first functional prototype of website, including content management system	June 16th - July 15th	55 [2]	3300
• Conducting simplified thinking aloud (n=5)	July 16th- July 18th	5 [1]	87.50
• Translating thinking aloud data into recommendations for website optimization	July 19th	4 [1]	70
• Processing thinking aloud recommendations into final version before website launch	July 20th- July 30th	10 [2]	600
Total	3 months	229 [3]	7195

Remark. The hours and cost do not include the man-hours (40 hours) spent by the infection control nurse to improve the content of the paper-based guidelines and make it suitable for web-based communication.

[1] Conducted by a student-assistant with an hourly rate of €17.50, including social security premiums.

[2] Conducted by an engineer with an hourly rate of €60.00, including social security premiums.

[3] Of these 229 hours, 154 refer to usability testing and 75 to website development.

3 Results

3.1 Traditional Thinking Aloud (Content)

Together, the 18 respondents worked on 192 tasks (10.7 tasks per respondent in 45 minutes, on average). Almost one third of the performed scenarios was not completed successfully (32.8%). Furthermore, it took the respondents an average of 199 seconds (3.3 minutes) to finish a task. Given that in reality, health care workers abandon a search after about two minutes, the effectiveness and efficiency of the paper-based guidelines can be rated as low [37]. The observations and the think-aloud verbalizations made clear what the main usability problems were. Table 3 shows the relation between the number of verbalizations and the type of usability problems.

Table 3. Overview of usability problems encountered when using paper-based guidelines (N=18)

Problem type	Frequency of problem	Percentage
Mismatch between nursing home staff's and expert vocabulary	167	42%
Incomprehensible information	100	25%
Incomplete information	69	18%
Inadequate information structure	54	14%
Inaccurate information	3	1%
Total	393	100

Table 2 shows that the tasks could not be completed successfully due to the following causes:

1. Mismatch problems (42% of problems): Respondents could not retrieve relevant information because of the volume of the guidelines (80 pages) and a mismatch between the search terms used by nursing home staff (e.g., "treatment") and the vocabulary applied in the guidelines (e.g., "decontamination procedure");
2. Incomprehensible information (25% of problems): Based on the information in the guidelines, respondents got even more confused about what to do in clinical practice, or did not comprehend the jargon used in the guidelines, e.g., the word "alkaline";
3. Incomplete information (18% of problems): For instance, the guidelines did make clear which protective clothing should be worn when entering an isolation room, but did not elucidate in which order the clothing should be taken on and off. Respondents indicated that the information was too concise to enable them to make a safe decision for clinical practice;
4. Inadequate information structure (14% of problems): For instance, nursing home staff expected to find the required information in a particular section of the paper document or by employing a specific search strategy, but the opposite appeared to be true, as the following citation illustrates: *"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." Other examples of information structure problems that were encountered with the paper-based guidelines were:

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

5. Inaccurate information (1% of problems): Outdated information, and a discrepancy between the guideline's rules and the possibilities of performing them in practice. E.g., the guideline requires each (suspicious) patient carrying a multiresistant micro-organism to be treated in preventive isolation, while on particular wards no isolation facilities are available.

We intended to prevent these problems by tailoring the website's functional requirements to the identified problems:

1. Mismatch problems and incomprehensible information: In order to communicate the guidelines' content to dovetail with nursing home staff's vocabulary, we used words on the website such as "get rid of bacteria" instead of "eradication therapy", "take swabs" instead of "perform screening cultures", "outbreak" rather than "epidemic situation", etc. A dedicated content management system enabled the infection control nurse to add and delete keywords to the search engine's database that aid in matching system with nursing home staff's vocabulary. Furthermore, mouse-overs were raised when the user moves or "hovers" the cursor over a word that they perceived as "difficult";
2. Incomplete information: Multiple key questions relating to everyday work practice were found for which the guidelines did not provide an adequate answer. Because we strived to provide nursing home staff with complete, comprehensible, and accurate guidelines that enable them to deliver safe health care, we included links, literature sources, pictures, videos, and other relevant multimedia examples to complement the guidelines;
3. Inaccurate information: Revision dates and the latest news were included in order to keep information accurate;
4. Inadequate information structure: Each guideline theme was presented according to a standardized format based on usability guidelines [38], with important items placed consistently at the top center. For each guideline, the standardized structure was: Title, target, indication, when to use, location, definitions, responsibilities, materials needed, correct procedure, comments, references. 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 enables users to keep track of their location within the system. Therefore, guidelines were retrievable through a search engine, a menu structure with categories, and frequently asked questions. The incorporation of three search options enabled nursing home staff to find the relevant information more rapidly with less effort (i.e., more efficient).

3.2 Card Sorting (Structure)

The Card Sort Study resulted in ten categories according to which the 59 themes derived from the guidelines content could be structured. The categories, each with an example to illustrate the practical approach of the website, are presented in Table 4. Compared to the general tables of content of infection control guidelines, it is remarkable that the search structure based on the Card Sort Study included a category on "To work or not to work", and a separate category on "Diarrhea". It appeared that nursing home staff desired a more action- and communication-oriented way of structuring information than is the case in current infection control guidelines. By employing a Card Sort Study, we tried to overcome problems with inadequate information structure. Since the categories' names were generated by the respondents themselves, usability problems caused by a mismatch in vocabulary and incomprehensible information were also prevented.

Table 4. Categories resulting from the Card Sort Study (n=18), each with an exemplary theme

Category	Example
Basic and hand hygiene	Am I allowed to wear nail polish during work hours?
Cleaning	Which products should I use in order to clean a client's po?
Definitions	What does the abbreviation PPM mean?
Diarrhea	How often should the toilet be cleaned in case a client has diarrhea?
How to act in case of an infection?	Which protective clothing should I wear when nursing a client with Anthony's fire (erysipelas)?
Laundry	Which precautions do I need to take with laundry of a client who has Methicillin Resistant *Staphylococcus aureus*?
Needles	Where should I dispose a used injection needle?
To work or not to work?	Am I allowed to work when I have weeping eczema?
Waste	Where to put paper and glass waste?
Wound care	Should I use sterile bandage in case of wound care?

3.3 Mock Up Prototyping (Lay-Out)

Our belief that a web-based format would improve the usability of the guidelines was strengthened by the findings of the traditional thinking aloud study. 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 infection control nurse to add and delete keywords to the search engine's database that aid in matching system's with nursing home staff's 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 nursing home staff's problems with the paper-based guidelines that resulted from the traditional thinking aloud:

1. Add practical, action oriented content (in order to avoid information quality problems), communicated in nursing home staff's vocabulary (to prevent matching problems);
2. Present guidelines in a multimodal way (in order to overcome information structure problems);
3. Consider different search strategies nursing home staff employ by incorporating three search options.

We applied these design principles next to usability guidelines when creating two non-working mock-ups [38]. The mock-ups each consisted of a homepage (see Figures 1 and 2). When asked to indicate their preference for one of the two mock-ups, 4 out of 5 respondents chose prototype 1, particularly because of "the convenient structure" (n=3), "the colors suit the theme of infection control" (n=4), and "the trustworthiness suggested by the logos of the involved organizations" (n=2). Prototype 2 was evaluated as "unattractive" (n=4) and "too gay (n=3)". Hence it was decided that the final lay-out of our website should be based on prototype 1. Asking users for subjective ratings of lay-out appeared useful. Even though respondents had different tastes and like and disliked different aspects of the mock-ups, one mock-up was disliked by four of five respondents. The constructive feedback given by the respondents was processed into the functional prototype of the website, which is depicted in Figure 3.

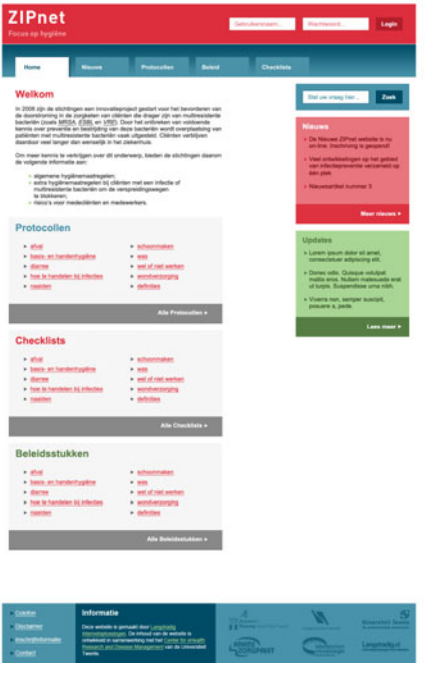

Fig. 1. Mock-up prototype 1

Fig. 2. Mock-up prototype 2

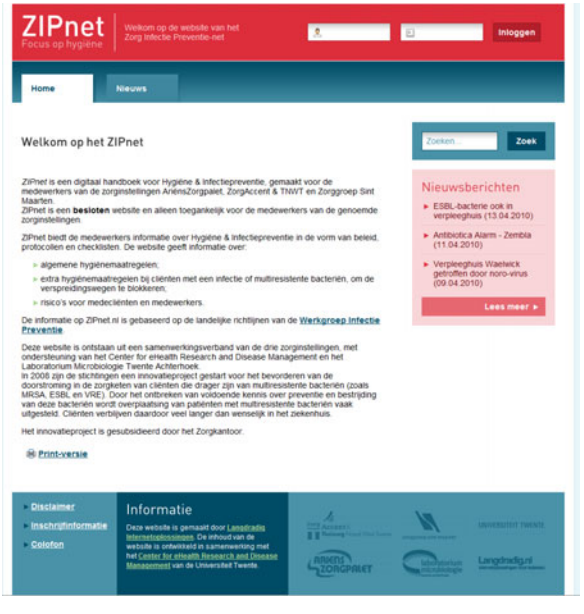

Fig. 3. Final version of the website's homepage (http://www.zipnet)

3.4 Simplified Thinking Aloud (Synergizing Content, Structure, and Lay-Out)

The results from each of the traditional thinking aloud, the Card Sorting, and the prototyping were integrated into a final working prototype of the website (see Figure 3). We undertook simplified thinking aloud in order to verify whether the problems that occurred with the paper-based guidelines were prevented with the web-based guidelines. All five respondents seemed to experience no difficulties when using the website. Almost every task was solved successfully within a time frame of 120 seconds. Each respondent immediately understood how the website had to be navigated through. They worked through the tasks quickly, and for the most part, determinedly. Respondents had little trouble understanding the guidelines and could translate the information to daily work practice.

It appeared that the amount of mismatch problems decreased due to the vocabulary that now matched nursing home staff's mental models. For the same reasons, information appeared to be more comprehensible compared to the paper-based guidelines. Information was perceived as complete, as the website allowed nursing home staff to decide upon the level of detail of the answer they wish to obtain, because next to the short answer, in-depth elaborations were provided, next to sources (e.g., scientific literature, newspaper articles, links to other websites for further reading, etc.). The multimedia examples (e.g., instruction movies and pictures of how to adequately apply personal protective equipment) were also highly appreciated. The respondents were enthusiastic about the information structure because important items were placed consistently at the top center, scroll stoppers were avoided as much as possible, and moderate white spaces were used. Also, information was not longer recognized as outdated: A dedicated content management system enabled the infection control nurse to add and delete information on the website at any time and location, which made that the respondents noticed the recently added news items.

The comments respondents made while thinking aloud, responses to the questions the researcher asked and remarks made during debriefing sessions, generated specific recommendations to optimally target the websites' content, structure, and lay-out to nursing home staff's needs. The most salient suggestions were:

Content. The mouse-overs, intended to be raised when nursing home staff moved the cursor over a difficult word, were not observed by the respondents. According to the respondents, the words to which a mouse-over was coupled had to be emphasized more explicitly. Furthermore, respondents mentioned that the risks involved in particular actions needed to be emphasized more clearly, e.g., through sparingly using underlines, bold, and italics. A colored background would be even better because underlining for emphasis can be mistakable for hyperlinks.

Structure. The order of the standardized structure (title, target, indication, when to use, location, definitions, responsibilities, materials needed, correct procedure, comments, references) according to which each guideline was presented, was not understood by every respondent. Respondents suggested that the order of the structural elements could better be changed: The main reason for using the website would be to look up the correct procedure. Therefore, the procedure should be placed on top of the page, followed by the remaining elements.

Lay-out. The news items, updates, and title were depicted in white text on a colored background (red, green, blue). However, respondents remarked that there was no sufficient contrast between text and its background and therefore, text was hard to read. Therefore, the background colors were set darker.

The recommendations suggested by the respondents were translated into practical design recommendations that the designer processed prior to website's final launch.

4 Discussion

4.1 Efficient, Effective, and Satisfying Process

The evaluation and usability methodology employed for discount user-centered e-health design proved to be both efficient and effective, and leading to high levels of satisfaction for the target group: nursing home staff [15, 39].

Efficient. The complete design process from the early beginning until the implementation of the websites took only 12 weeks and led to a rapid and consensual decision. The total cost of the process was less than 7200€ including the design and implementation of the application itself, the usability studies, and the project staff's fee. No additional equipment or room space was needed for the observations. Overall, time spent on planning, executing, reporting, and presenting the evaluation was approximately 229 hours.

Effective. Although we used a discount approach, the results proved to be very informative and efficiently supported the decision making process. Although our methods were fast and cheap, they still met the three principles of user-centered design: early focus on the user, empirical measurement, and iterative design [19]. The process led to a realistic choice for a website. The test report was sent to managers from participating wards of the various nursing homes. Several of them decided to invest in user-centered design for the design and implementation of other communication devices within the nursing home setting.

Satisfaction. The final choice of the website was strongly and positively by the results of the user-centered discount approach.

4.2 Benefits of Discount User-Centered e-Health Design

Based on our findings, we would advocate using this discount user-centered design approach for the design of e-health applications. The philosophy of involving end users and other relevant stakeholders rightly fits the concept of participatory health care. Effective health care requires productive interaction between activated patients and a prepared practice team [40]. In its landmark 2001 report on Crossing the Quality Chasm, the Institute of Medicine named "patient-centered care" as one of the fundamental aims of the health care system, to spearhead the concept that healthcare should be centered on the individual patient's needs, wants, and perspectives. Benefits of patient-centered care or patient participation include enhancing patient's knowledge

about health concern, patients are helped to understand the decisions that health care providers make daily, collaboration between patient and provider frames discussions, and patients' empowerment to take action in their own healthcare process [41]. Several new concepts have risen, all with an identical meaning to patient-centered care such as "shared decision making" or "participatory medicine" [42]. When applying user-centered design for the development of e-health applications, stakeholder involvement might be enhanced, which creates ownership, fosters applicability of the application, and leads to a willingness to integrate the application into routine care. The intensive participation of the users in our test sessions greatly improved their knowledge of the project. At the end of the test weeks, a nursing home employee would have had to be deaf and blind not to know about the project and its content. Other scholars also emphasized this benefit. E.g., Petit Jones claims that "discount usability engineering results opened dialogue about usability issues (…) and helps secure more time to address usability on other projects. [43]"

Thus, user participation is increasingly recognized as a key element of the overall quality of healthcare, which might be supported by user-centered e-health design. However, involving relevant stakeholders in the design of health care applications has not become a standard procedure yet. Several barriers exist in realizing patient participation, such as financial constraints, fatigue and competing priorities, and a lack of tools to gauge and reward user-centered care. In other words: an efficient and effective mix of instruments and participants has not been identified yet. In here, discount user-centered design might serve as a solution. With our study, we identified a discount approach for user-centered design of a completely new e-health application within a time frame of three months, for cost lower than 7500€. The following factors enabled us to develop a user-centered website with infection control guidelines with such a restricted budget of time and money:

- Case-driven: No expensive laboratory had to be rented, nor had any expensive recording equipment to be purchased. A simple digital voicerecorder sufficed.
- Small sample size: Since the results did not have to be generalizable to the complete Dutch population, and five respondents were enough to detect at least 75% of user problems, we only needed to include few participants.
- Online, free software: Part of the analysis was conducted through online, free software: A trial version of WebSort™.
- Method of analysis: Data analysis of the second part of the study (prototyping, simplified thinking aloud) was solely based on the researcher's notes instead of data transcription, which saved time and thus money.

Our study was not the first attempt "to improve a system in the shortest time with the least effort" without performing extensive and formal usability evaluation, while at the same time preventing that results are completely worthless. Other researchers also discussed at what level discount usability methods are fast and cheap, but not so fast and cheap that they are no longer valid. E.g., Marty and Twidale [24] explored the value of discount usability engineering at extremes of times and tests, with conducting 36 entire evaluations in only thirty minutes. Kjeldskov, Skov and Stage [23] presented a data analysis technique which allows usability evaluations to be conducted, analyzed

and documented in one day. Both Marty et al. and Kjeldskov et al. looked at the percentage of critical usability that the methods raised compared to standardized, formal usability evaluations. Our study however, was targeted not so much at comparing new discount methods to traditional usability engineering, but to identify a discount approach for user-centered design of a completely new e-health application (without a prototype being available). We achieved this by combining traditional thinking aloud and Card Sorting with the discount usability methods of prototyping and simplified thinking aloud, and by omitting heuristic evaluation. The findings of our study open a relatively unexplored area of the user testing continuum. Many usability evaluators make the rigid distinction between academic research on the one hand and pragmatic research on the other, with in between a huge gap [24]. Our study demonstrated that a compromise between the two is fairly possible, with the combination of traditional thinking aloud and Card Sorting on the one hand, and mock up prototyping and simplified thinking aloud on the other hand. Because the user has a more active role in our approach, we claim that our discount approach is more user-centered compared to the standardized discount approach suggested by Nielsen [19].

4.3 Study Limitations

The results gathered in this study need to be recognized as having a "real world application". In other words, the test results are not suited to test statistical significance. Certainly, for much research, one needs to have a high degree of confidence that the findings are not subject to chance. For the design of usable e-health applications however, one can be satisfied by less rigorous tests like those we conducted [19]. In other words, even tests that are not statistically significant are well worth doing since they will improve the quality of applications substantially. Although the methodology used in this study did not follow scientific standards, the results should be considered as relevant as scientific-based results and applicable in the real world [14].

Maybe, better results would have been achieved by applying more careful methodologies. However, more careful methodologies are also more expensive in terms of time and money, and also in terms of required expertise. For instance, a more extensive analysis of the data, particularly of the simplified thinking aloud tests with the website, would have produced a more detailed description of each of the identified usability problems. The simplified data analysis did not provide this detailed information but merely produced a list of shortly described problems. For the purpose of a scientific comparison between the paper-based and web-based infection control guidelines just like in Verhoeven et al [4], the thinking aloud data should have been recorded and transcribed verbatim. Previous research with traditional thinking aloud as a user test method of the website demonstrated the chosen approach (traditional thinking aloud, Card Sorting, mock-up prototyping) to be valid (see [4]). When we would have applied a more rigorous user evaluation of the website, the method could not have been called a discount method any longer.

Therefore, the simpler methods stand a much better chance of actually being used in practical design situations and they should therefore be viewed as a way of serving the user.

4.4 Future Research

In future research, it would be interesting to address the following issues:

Integrate methods of participatory design in discount usability engineering. In participatory experiences, the roles of the designer and the researcher blur and the user becomes a critical component of the process. The new rules call for new tools, by which users can express themselves and participate directly and proactively in the design process. Traditional design research methods were focused primarily on observational research (i.e., looking at what people do and use). Traditional market research methods, on the other hand, have been focused more on what people say and think (through focus groups, interviews, and questionnaires). New methods for participatory design should be more focused on what people make, i.e., what they create from the toolkits we provide for them to use in expressing their thoughts, feelings and dreams. Co-design methods such as probes, probe diaries, workshops, user sketching, low-tech prototyping, sticky-note feedback, and distributed collaboration might serve as a promising solution in here [45, 46]. For instance, a recent study showed that user sketching facilitated thinking, reflection, and discovery for respondents and resulted in receiving more reflective feedback. Tohidi et al therefore recommended the use of this practice as a quick and inexpensive addition to other commonly used practices. They believe that sketching has the potential to be developed into a light-weight form of usability testing, due to its relatively low cost in time demands for analysis [46]. Future studies should investigate the benefits of these creative co-design or participatory methods for discount usability engineering.

IntegrateWeb 2.0 research methods in discount usability engineering. Next to creative research methods, online research methods could also contribute to the feasibility of discount usability engineering. Studies conducted online are not only less error prone and labor intensive but also rapidly reach large numbers of diverse participants at a fraction of the cost of traditional methods. In addition to improving the efficiency and accuracy of data collection, online studies provide automatic data storage and deliver immediate personalized feedback to research participant; a major incentive that can exponentially expand participant pools. Furthermore, behavioral researchers can also track data on online behavioral phenomena, including Instant Messaging, social networking, and other social media [47]. Involving stakeholders and end users via social networking platforms creates new levels of participation. Web 2.0 tools such as social networking sites, blogs, podcasts, tagging and communication tools stimulate "apomediation", which is the phenomenon that users can help other users navigate through the wealth of information afforded by networked digital media, providing additional credibility cues and supplying further meta-information [42].

5 Conclusion

Our main research question was: Are the available, existing discount usability methods suitable for the design and development of new e-health applications, or do other research methods have to be incorporated? We claimed the latter to be true. For the case of this study, we adapted Nielsen's discount usability approach because (1) we deemed

it less appropriate for the design of *new* applications (for which no prototype is yet available) and (2) heuristic expert evaluation, which is part of Nielsen's discount approach, will not play its full right given the fact that in our case, the expert-driven character of documentation is the major cause of usability problems. Therefore, we complemented Nielsen's methodology with traditional thinking aloud to make it suitable for new applications, and replaced the heuristic evaluation with a more user-centered method: Card Sorting. Together, the methods generated the optimal content, structure, and lay-out for a website with infection control guidelines for nursing homes. We intended to demonstrate that although our method is quick, it definitely is not dirty, since our methodology is based on scientific design principles and still enables data analysis at an academic level. Based on our findings, we would advocate using this discount user-centered design approach for the design of e-health applications. Next to this advice, we believe the design principles for web-based communication of infection control guidelines this study generated may also be helpful to others engaged in the infection control setting.

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