Keeping an eye on the context:

Participatory development of eHealth to support clinical practice

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Illustratie omslag: Sovianne ter Borg

Print: Gildeprint Drukkerijen, Enschede, The Netherlands

ISBN: 978-90-365-3978-4

DOI: 10.3990/1.9789036539784

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KEEPING AN EYE ON THE CONTEXT: PARTICIPATORY DEVELOPMENT OF
EHEALTH TO SUPPORT CLINICAL PRACTICE

PROEFSCHRIFT

ter verkrijging van
de graad van doctor aan de Universiteit Twente,
op gezag van de rector magnificus
Prof. dr. H. Brinksma,
volgens besluit van het College voor Promoties
in het openbaar te verdedigen
op vrijdag 23 oktober 2015 om 16.45 uur

door

Matthea Jobke Wentzel
geboren op 19 augustus 1984
te Warnsveld

Dit proefschrift is goedgekeurd door de promotor prof. dr. J.E.W.C. van Gemert-Pijnen en copromotoren prof. dr. R. Sanderman en prof. dr. A. Friedrich.

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Chapter 1. General Introduction

Introduction

Every year, millions of patients in the EU alone contract infections during their stay in a hospital or another health care facility [1]. These healthcare-associated infections severely compromise patient safety and can ultimately lead to death. Especially infections caused by pathogens that have become resistant to one or multiple forms of antimicrobials can cause much harm, because they are difficult to treat due to their antimicrobial resistance [2]. As a consequence, these resistant pathogens need to be detected and isolated as quickly as possible, before they spread onto others (within or even outside the facility). Besides a strategy of 'search and destroy', prevention is key to warrant patient safety [3]. Implementation of and adherence to infection prevention and control strategies are necessary to combat healthcare associated infection. In addition, prudent antimicrobial use should be practiced to limit the development of antimicrobial resistance. However, implementing interventions that support rational antimicrobial use and infection control in clinical practice unfortunately remains rather challenging [4]. In fact, a gap exists between expert-driven guidelines and actual everyday care practice and it results in complications for implementation because healthcare workers cannot understand or apply the information in practice [5].

In this thesis, the focus is placed on how technology, created with healthcare workers and other stakeholders, can support patient safety via persuasive information interventions. In the following paragraph, a description is given of the main mechanisms causing a threat to patient safety regarding healthcare-associated infections and antimicrobial resistance. Thereafter, the ways information and information technology in health care, or eHealth, can contribute to patient safety are explored. Next, an overview of the CeHRes Roadmap is given. This roadmap was applied throughout this research and forms the basis for developing and evaluating eHealth technology in a holistic manner. Hereafter, the research questions that form the basis of this thesis are introduced. An outline of the chapters of this thesis concludes this introduction chapter.

The need for cross-border infection prevention and control

Increasing antimicrobial resistance and increasing globalization and migration, especially in healthcare settings, pose threats to patient safety. This asks for a multidisciplinary and border-crossing approach. People and healthcare workers are increasingly migrating, and experience less physical and legal borders to consume or provide healthcare outside their own region or country. Unfortunately, infectious threats travel alongside human or livestock migration flows, and can spread more easily due to increased cross-border mobility (in healthcare and agriculture) [6, 7]. The nature of infectious threats calls for information sharing and cooperation on various levels: between individual health care workers of various professions, healthcare institutions, municipalities, regions, and countries [6, 8]. For example, antibiotic guidelines are issued by national institutes such as

the Dutch Working Party on Antibiotic Policy (Stichting Werkgroep Antibiotica Beleid, SWAB), or Robert Koch Institute (RKI, Germany). Besides national guidelines, individual hospitals are recommended to translate these guidelines to local protocols for prudent antibiotic use, in which they take into account local or regional antimicrobial resistance patterns. Via these guidelines and recommendations, healthcare professionals and patients are informed about what they should do to prevent infectious diseases and pathogens from spreading. In addition to infection prevention and control measures for clinical practice, infectious disease experts at local, national, and international levels need to evaluate spread and prevalence of pathogens, and adjust recommendations and guidelines accordingly. In particular, appropriate antimicrobial use in human and livestock

Box 1: Cross-border cooperation in EurSafety Health-net

Forces are bundled and a holistic approach is applied in the EurSafety Health-net project. This project aims to improve cross-border patient safety regarding infection prevention and control. It builds on experiences from MRSA-net. In the MRSA-net project, cooperation and effective implementation of MRSA control measures were supported by technology that was developed by applying a human-centered focus [5, 8]. This cooperation is expanded in EurSafety Health-net [9], where the formation of cross border networks for cooperation and digital solutions are further explored. In addition, technology is developed to support all stakeholders in accomplishing safer patient care. Further, by applying a behavioral approach, sustainable behavior change is supported. In this approach, a focus is put on humans or persons functioning in an organizational or networked context. Examples of (inter) regional cooperation include quality seals for nursing homes, sharing and studying of prevalence data on both sides of the border, and sharing of guidelines and best practices. Key to this project is the need to understand the drivers of behavior (e.g., guideline adherence, or information sharing), so that solutions can be tailored to the situation of individual actors. This calls for a socio-technical approach that crosses borders of professions, institutions, regions and countries [10]. This approach becomes visible in initiatives such as the antimicrobial stewardship programs that aim to connect stakeholders (clinical microbiology, physicians, wards, pharmacy) and share information [6,8].

(agriculture) care is of importance for cross-border patient safety, because excessive and irrational antimicrobial use is associated with resistance forming [3]. Even though the exact nature of this relation is not fully clear, the consequences of imprudent antimicrobial use pose direct and indirect risks for individual patients and society. In the care process, various stakeholders are touched upon by interventions or regulation concerning infection control or antimicrobial use, all with their own stakes, values, and needs. The EurSafety Health-net project [9] addresses the need to cross borders in healthcare, with a focus on infection control (see box 1). By joining forces on various levels through cooperation and information

sharing, better adjustment to and timely measures to combat infectious threats can be accomplished [10].

So, local and networked solutions, adjusted to the specific situation and needs of a region, institute, or (group of) healthcare workers are called for. In addition, besides the need to cross institutional or national borders, borders between (scientific) disciplines need to be crossed improve patient safety [10]. Traditionally, a medical perspective is applied to reach such solutions, focusing on a cure (protocol), and overlooking necessary behavior change of involved actors to achieve successful implementation. Therefore, approaches that include a behavioral perspective aimed at behavior changes are relevant in infection control, and multidisciplinary cooperation is called for [11]. In addition, technology-facilitated interventions that match the social or organizational context in which they are implemented are needed.

However, such holistic approaches are scarce, even though examples of a focus on the human factor in infection control strategies exist, e.g., [12]. In addition, a focus on the application of behavioral theories to improve infection control guideline adherence has been proposed [5, 13]. In a previous project this thesis builds upon, a website was created with users and infection control experts. Via this website, expert-driven protocols on Methicillin Resistant *Staphylococcus Aureus* (MRSA) were tailored to the information needs of health care workers and the general public [11, 14]. This work convincingly demonstrated the value of a user-centered perspective [5]. The approach of supporting behavior by technology opens up opportunities in the field of infection control and protocol communication that are further explored in this thesis. These potentials of technology to support patient safety is discussed in the next paragraph. Possibly, to overcome issues with implementation, technology may prove to be the linking pin.

Technology to support patient safety

Technology enables the provision, sharing, and processing of information, tailored to specific (local) user group needs. eHealth solutions aim to support health via information and communication technology, aimed at the general public, patients, or healthcare professionals. Or, as Eysenbach defines it: “e-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve healthcare locally, regionally, and worldwide by using information and communication technology” [15]. In the EU, the relevance of eHealth is acknowledged as a means of innovating healthcare and improving health: “eHealth is the use of ICT in health products, services and processes combined with organizational change in healthcare systems and new skills, in order to improve health of citizens” [16].

In hospital settings, eHealth technology conquers ever more ground, with varying levels of acceptance and satisfaction. Many technological solutions have great improvements to offer in patient safety, effectiveness of treatment, knowledge (among patients and professionals), and efficiency. However, its full benefit has not been reached [17-19]. Developing and implementing technology in a clinical setting may be an exceptionally challenging activity, because it is difficult to assess the precise context, user needs, and technology requirements. This may be due to limited time, and resources are limited and geared towards the core and most urgent stake (patient care) [20]. Nevertheless, eHealth initiatives are booming. For example, a great variety of medical applications is available for smartphones [21] and go accompanied by a discussion on the need for quality control of such apps [22]. So, besides obvious opportunities of eHealth, drawbacks are not unknown [23-25]. These drawbacks possibly account for the sometimes lacking acceptance and skeptical attitude among healthcare professionals and patients towards technology. A person's health is crucial and after a bad technology experience it is hard to restore trust and enthusiasm.

In case of infectious disease or threats, the amount and timely supply of the information needed calls for smart technological solutions. In infection control settings, decisions need to be made, taking into account general protocols, hospital-specific protocols, patient background, test or diagnostic results. In addition physician, nurse, and other healthcare professionals' observations of the patient should be considered. Often, this dynamic care process is already supported in various ways, via e.g., digitalized reference books, patient information, alerting systems, reminder systems, and decision support systems. [26-30]. In such technologies, functionalities are combined to better serve the users. For example, a medication registration system may warn for dangerous interactions of two medications, send reminders when a patient has not received a prescribed medication on time, and offer the possibility of looking up background information on a certain drug. Likewise, patient platforms have been set up where patients can look up information on a certain condition, do an e-consult when they have a specific question, or manage their progress based on lab results and previous physician visits [31-33]. For healthcare professionals, support in reaching a diagnosis or choosing the best course of action within a treatment is operationalized in decision support systems [13, 29, 34].

The attunement of functionality, design, and content to the needs that exist in a specific healthcare setting, can contribute to the system's use and effectiveness [35]. In this sense, high tech is valuable, but applying a human touch to technology is of paramount importance to enable adherence [36] and a fit with practice. A great challenge remains in how to weigh needs and involve the right stakeholders in technology development. The CeHRes Roadmap [37] provides a rationale and practical recommendations for this challenge, as the next paragraph further describes.

The CeHRes Roadmap

The Centre for eHealth Research and Disease management (CeHRes) provides a “roadmap”: a guideline for the participatory development and implementation of eHealth technology [37]. It offers an approach to systematically anticipate on stakeholders’ (e.g., healthcare workers, management) needs and values, and to guide design and facilitate implementation. Especially during early stages of development, stakeholder involvement is crucial to create sustainable technologies. A participatory development approach can help to overcome mismatches between work practice and technology. This can be done by checking findings regarding needs, context, and possible design, and functionalities with various relevant stakeholders during every stage of development [38]. To ensure that solutions or technologies are actually implementable and sustainable, a business modeling approach needs to be applied throughout all development phases. Various activities can be carried out to gain an understanding of the eventual business model that should be applied, making clear who contributes, benefits and/or uses the technology. In addition, activities focus on clarifying what cost and revenue flows are to be expected (including value creation) and how resources (monetary or otherwise) should be applied [39]. In this thesis, the CeHRes Roadmap facets are applied (a holistic approach), and a special focus lies on how a system can influence behavior and support tasks and skills.

One of the strategies described in the roadmap that may facilitate implementation, uptake, and effectiveness of eHealth applications, is to incorporate Persuasive Systems Design (PSD) into technology. In the PSD model, users are persuaded (and not coerced or deceived) by a technology which reinforces, shapes, or changes behavior [40]. An analysis of the target group and its context guides the decision on persuasion strategies to apply. These strategies include: primary task support, dialogue support (facilitating interaction with the system), credibility support (credibility of the system and its content), and social support (interpersonal interaction or comparison via the system). The strategies are operationalized via design principles. For example, including tokens of expertise (regarding content) in a system contributes to credibility support [40]. Designing technology in such a way that it is unobtrusive, useful, and easy to use helps to blend the technology seamless into users’ work (or life) and quickly reach their goals. The model is applied to the design and evaluation of health interventions aimed at (changing health behavior of) patients or non-professionals [41], but the principles apply to professional-aimed eHealth technology as well [42].

To be able to make technology persuasive, a study of the users’ context is promoted within the PSD model. Likewise, contextual inquiry is an important phase of the CeHRes roadmap. This focus on users and their context seems a valid approach, because too many examples exist of technology that cannot be used by the intended target group or is used in other un-intended (and suboptimal) ways. Often, the cause of this suboptimal

use lies in a mismatch between technology features and actual user needs, preferences, and capabilities. This may lead to technology solving problems that do not exist, technology that does not blend into daily life or practice, technology that does not appeal to the user, or technology that is unnecessarily complicated and too difficult to use (user-unfriendly).

To study user context and ensuring design matches with user contexts and needs, developers and designers are encouraged to take a more user-centered perspective [43]. This means that the people who use or are affected by the technology are placed central during development and design, and may even co-create. Human-centered design offers such an approach and focuses on the human touch in technology. Involving users (and/or other stakeholders) via a participatory development approach or by applying co-creation, leads to insights in and a fit with reality that is exceptionally hard to reach by developers on their own [44]. Development cycles often include one or more of these (iterative) activities: orientation/context study, ideation, prototyping, user testing [43, 45].

Research Questions

The “ingredients” described in the former paragraphs can lead to a socio-technical approach that aims to change behavior via technology support. Such an approach is not exercised by default in the field of infection control. However, this field may benefit from a such a holistic approach that helps to overcome issues in guideline adherence. In addition, the relative novelty of the CeHRes roadmap asks for operationalization in research practice. In this thesis, all phases from design to summative evaluation of the roadmap are applied and evaluated upon, with the concurrent aim of developing eHealth that supports patient safety. The main research question therefore is:

How can technology provide information support for safe healthcare and decision making in clinical context, using the CeHRes roadmap?

Sub-questions are twofold and include (case-specific) technology issues following the development of an application:

What content, functionalities and design are needed? (chapter 2,3 5)

What preconditions for implementation should be in place? (chapter 4, 5)

Besides these practice-focused questions, this thesis zooms in on the following CeHRes roadmap assumptions regarding research, methodologies, and generalization of the approach:

What does human-centered design contribute to the support of safe patient care via technology? (chapter 2,6)

How can the roadmap’s methodologies enable the detection and application of user- and stakeholder needs and preferences? (chapter 2,3,5,6)

To what extent does this approach lead to efficient eHealth technology? (chapter 6,7)

Outline of this thesis

The chapters of this thesis roughly correspond to CeHRes roadmap activities, starting with a contextual inquiry. First, a contextual inquiry was initiated, and was triggered by lessons learned from the development and implementation of the MRSA-net website. Chapter 2 describes the development and overall evaluation of MRSA-net, addressing the sub-questions 1, 3, and 4.

Hereafter, in chapter 3, we elaborate on the lessons learned from applying the human-centered methodology of card sorting. In this chapter, an evaluation of the long-lasting validity of the design as was derived from a card-sort study was done, to assess the robustness and additional value of this method. Answers to sub-questions 1 and 4 stem (partially) from this chapter.

Thereafter, a review of the scientific literature concerning implementation strategies for MRSA prevention and control guidelines further complements the contextual inquiry and provides answers to sub-question 2 in chapter 4. The aim of this study was to evaluate what strategies were used to implement guidelines into clinical practice, and if (and how) technology plays a role in this process.

The review findings were then combined with further inquiry into the context of antimicrobial stewardship, a value specification, and insight into design preferences for the development of an eHealth application. This application was created to promote patient safety by supporting antimicrobial stewardship, described in chapter 5. This chapter addressed sub-questions 1, 2, and 4. The outcomes of the human- (and stakeholder-) centered activities of the study described in chapter 5 have led to the development of the antibiotic app, an application aimed primarily at nurses in clinical settings.

To what extent the process of human-centered design and stakeholder involvement produced an effective, user friendly, and efficient application is under study in chapter 6, where the effects that were found in the pilot study of the antibiotic app are described, addressing sub-question 3, 4, and 5.

Finally, in order to understand application success (or lack thereof), we assessed the application's perceived persuasiveness and use. This final study on application use (log data) and persuasive elements follows in chapter 7 and addresses sub-question 5.

This thesis ends with a general discussion of the main findings in chapter 8, including conclusions and recommendations for further research.

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Chapter 2. Development and evaluation of MRSA-net

This chapter is based on:

Van Gemert-Pijnen, L., Karreman, J., Vonderhorst, S., Verhoeven, F., & Wentzel, J. 2011. Participatory development via user- involvement - A Case Study about the development of a Web-based Patient-communication system about Methicillin-resistant *Staphylococcus aureus*. *Electronic Journal of Health Informatics*, 6(4):e28.

Abstract

This paper describes the participatory development process of a web-based communication system. The system aims to support disease management, particularly infection control of Methicillin-resistant *Staphylococcus aureus* (MRSA). These infections are becoming a major public health issue; they can have serious consequences such as pneumonia, sepsis or death. This makes it even more important for people to be provided with up-to-date and reliable information. Users of a bilingual communication system (Dutch and German) participated in the development process via a needs assessment, the co-creation of the content and the system via usability tests, and in the summative evaluation of the usage of the system. The system enabled users to search efficiently and effectively for practical and relevant information. Moreover, we found that the participation of the intended users is a prerequisite to create a fit between the needs and expectations of the end-users, the technology, and the social context of use. The summative evaluation showed that the system was frequently used (approximately 11,000 unique visitors per month). The most popular categories include 'MRSA in general' (20%, both languages) and 'Acquiring MRSA' (17% NL, 13% GER). Most users reach information pages using internet search engines (Google) instead of the on-site search engine. When they are on the site, users prefer convenient searching via FAQ or related questions. Furthermore, the results showed that the participation of stakeholders is a prerequisite for a successful implementation. To guide the participation of stakeholders we developed a roadmap that integrates human-centered development with business modelling activities.

Introduction

The participatory development of eHealth technologies is an approach that is used to maximize the fit between the technology, its intended users and other stakeholders like payers, providers, decision-makers, and the environmental context in which the technology is used [2-4]. By participating in the development process, the intended users are involved in creating a technology that meets their expectations. At the same time, this creates a sense of ownership and trust in the technology to be developed [5-10]. User-involvement in eHealth technologies is highlighted in several studies but is often limited to the design stage: testing the prototypes [11]. In our view, users have to be involved continuously, right from the start of thinking about a certain technology that aims to support health promotion [4, 12]. User-involvement is particularly important in the case of communication geared towards managing diseases that have an impact on the quality of life [13].

From prior research we know that web-based technologies are valuable because of the capacities to attune the information to users' needs and their mental models about risk-management [14-15]. A second benefit of web-based technologies is that it is easy to provide multi-media instructions (text, graphics, and videos) [13]. A third benefit is the opportunity to consult information irrespective of time and place and without having to involve other care professionals; a benefit for people with taboo problems like infectious diseases.

Since infectious diseases like Methicillin-resistant *Staphylococcus aureus* (MRSA) are ever more prevalent among healthy people, animals, and in raw meat. Since infectious diseases can have serious consequences such as pneumonia, sepsis or death, they are becoming a major public health issue [1, 16-17]. Consequently, it is even more important now for people to receive up-to-date, trustworthy, and consistent information. In the case of MRSA it is very important that people know what has to be done in the event of an outbreak. However, we know from prior research that patients or members of the general public have limited knowledge about this, that misconceptions exist, and that most of the information available seems too medical for a lay-person to understand [14].

Apart from informing the general public, it is important to provide those people who are colonized or infected with MRSA with the information they need. Being colonized or infected appears to have a large impact on the carrier's daily life. Since MRSA is very contagious, patients with MRSA have to be hospitalized in isolation, and also take numerous precautions at home, such as maintaining a strict hygiene regime and avoiding any contact with ill people. Consequently, harboring MRSA in the home situation has been associated with adverse effects such as anxiety, depression, and reduced quality of life, as well as indirect effects such as being denied access to healthcare facilities [18].

In order to decrease anxiety and dispel any feelings of uncertainty among MRSA-carriers (patients with MRSA), it is of vital importance to provide them with reliable, consistent information at all times regardless of where they live or what time of day it is. Previous research indicated that MRSA-carriers perceived current education as deficient and misleading [18]. In addition to this, healthcare providers were perceived as unprofessional since they could not answer relevant questions. Our goals, therefore, were to improve education for MRSA-carriers in the home situation by developing a web-based communication system that meets both cognitive (practical) and affective (personal) information needs. In addition, we aim to provide healthcare providers with information that is easy to access and use. The communication system consists of two parts: one aimed at patients and the general public, the other aimed at health care workers. This study focuses on the first part.

The societal objective of this study is to develop a web-based system that enables MRSA-patients and members of the general public to efficiently and effectively search for practical and relevant information that can support them in their efforts to cope with the MRSA infection and empower them to take appropriate measures to prevent outbreaks and further complications. This study is part of an international project, MRSA-net (<http://www.mrsa-net.nl>) that aims to control MRSA and facilitate patient safety via cooperation and information sharing for both health care workers (HCWs) and patients or the general public.

The design of most educational resources directed at MRSA-carriers relies primarily on the conventional wisdom of experts, rather than on an evaluation by its intended target group. It is therefore not surprising that MRSA-carriers often miss the point and become confused. To overcome this problem, we applied a participatory development approach, involving the primary target group; MRSA-carriers. We expect that this system will not only be used by this primary target group, but also by a secondary target group. This secondary target group consists of patients' relatives and members of the general public who are interested in, or worried about, MRSA because MRSA is observed more and more in the community (CA-MRSA). In the first stages of our participatory development process, we concentrated on patients, the primary target group, to attune the protocol-based information to their needs. The summative evaluation includes data from all users; patients, members of the general public and also HCWs. The research objective is to determine the extent to which a participatory development process can be supportive for developing human-centered eHealth technologies, as opposed to expert-driven information systems.

Methods

Participants in the study consisted of patients that had been (formerly) colonized or infected with MRSA. Their contact details were obtained by infection control nurses from various hospitals and public health institutions in the Netherlands. Respondents participated in the process at their own convenience. Data was collected continuously throughout the development, between March 2007 and September 2008. A summative evaluation is being performed on usage data available since the tool's launch in February 2008 up until December 2010. The summative evaluations started in September 2010.

The system's target audience includes patients and members of the general public as well as HCWs. However, as their (information) needs differ, the development process was carried out separately. This study focuses on patient participation. HCWs were involved in the development process in a similar way. The development process described in this study consists of four methods for ensuring the involvement of users (1) contextual inquiry (needs assessment), (2) design via Card Sorting, aimed at creating the content and navigation structure of the web-based system, (3) usability testing of the first working prototype and (4) summative evaluation of the usage in practice via log files to assess the pragmatic value of the web-based system.

(1) The contextual inquiry (a needs assessment) started with a systematic analysis of MRSA-carriers' information needs in order to obtain input for the system's content. Semi-structured interviews with 22 MRSA-carriers based on stress- and coping theories [19] were carried out to investigate cognitive and affective information needs. Three types of MRSA-carriers were involved: people with Community Acquired MRSA (CA-MRSA; n=6), Hospital Acquired MRSA (HA-MRSA; n=8), and Veterinary Acquired MRSA (VA-MRSA; n=8). The interviews generated 220 key questions that caused feelings of stress among MRSA-carriers, but remained unanswered by current information providers. Finding these answers is nevertheless required to cope with MRSA in daily life. The current information is based on brochures and infection protocols for personnel rather than patients.

(2) Design of the content and structure of the web-based information system via a Card Sort study among 10 of the interviewed MRSA-carriers and Mockup-prototyping. Card Sorting is often applied as a user-centered method for designing a website's menu structure [20]. Respondents sorted a selection of 100 out of the 220 questions into meaningful groups that eventually served as the system's navigation structure. Subsequently, two mock-up prototypes of the homepage and the search page were created, based on common guidelines for web design and usability [21-22]. We interviewed five different MRSA-carriers to evaluate the prototypes shown on a laptop, and based our choice for the final lay-out of the system on the results. We checked whether or not the information conflicts with the standard precautions for infection control (National MRSA guidelines).

(3) Usability testing of real-time usage. The evaluation was carried out immediately after the first prototype was developed. The first working prototype of the web-based system was evaluated among 18 other MRSA-carriers by means of scenario-testing; a method commonly used to determine website usability [21]. The sample consisted of people that carried CA-MRSA (n=3), HA-MRSA (n=4), VA-MRSA (n=4), people that had been suspected of carrying MRSA and were therefore treated in quarantine in the hospital (n=3), and four representatives of the general public (n=4). The scenario method is of high value, since users are in a unique position to provide early, authentic feedback and it enables the researcher to explore problems encountered while real users work with the website [23]. Respondents carried out scenarios that represented the information needs identified in the needs assessment, while thinking aloud. For example: *"You are colonized with MRSA and you would like to know whether you can visit your ill grandmother. Using the web-based system, can you say aloud what you need to do?"* The results demonstrated how far MRSA-carriers' cognitive and affective information needs were met. The inadequacies that were detected during the scenario-based tests were fixed before the system was officially implemented.

(4) Summative evaluation is performed by analyzing the available log files. MRSA-net use has been logged since its launch and we thus have empirical data of more than 2 years of use. This comprises both usage data of activity on the HCW part of the system as well as usage of patient-aimed content. The data on general use are available via the built-in web statistics program (AWSTATS). This data shows the number of visitors, page views, users, entry and exit pages, etc. that have been logged since March 2008 until the end of 2010. To give an indication of the dataset's size: in 2009, the web-based system (<http://www.MRSA-net.nl>) was visited 154,894 times with on average 4.33 pages viewed per visit.

In addition, specific pages that were accessed have been extracted and compiled in a dataset that offers more precise information about individual user actions: visited content type (general public or HCW, German or Dutch), used search strategy (on site search engine, frequently asked questions, or topic selection), viewed answer, and session duration. These log files show us how MRSA-net is used and, to some extent, by whom. In other words, these files provide a 'digital fingerprint' [24] of MRSA-net users. Similarly, information accessed on certain topics within MRSA-net can be identified and the extent to which the website fulfils the information needs of its users can be demonstrated through analysis. In this study we focus on the participatory development approach of the web-based system and its usage by patients and members of the general public.

Results

In this section, the results of the different methods used for developing the web-based system will be presented consecutively.

Contextual inquiry: needs assessment

Being colonized or infected with MRSA turned out to be a stressful experience. In most cases (52.5%) of stress mentioned, the stress was caused by factors on the affective or personal level (e.g., feelings of stigmatization, fear, depression) and cognitive level (e.g., lack of knowledge). In 20% of cases, MRSA-carriers used emotion-focused coping strategies to deal with the stress, such as venting feelings, seeking social support, or distraction. In 75% of the stressful events, information-seeking strategies were used to cope with the stress. Sixteen respondents (73%) indicated that they had consulted the internet in order to look for MRSA-related information. However, in 83% of cases, the required information was not successfully identified. Other information sources that were consulted included brochures, information leaflets, or healthcare providers (public health institutions in particular).

We discovered 385 incidents of information need, either of a cognitive nature or an affective/personal nature. Cognitive information needs involved:

- General information (122 incidents), such as: "What is MRSA?", "To what degree can I contaminate others?", "Where does MRSA come from?", etc.
- Information regarding the hospitals' MRSA-policy (49 incidents), such as "Why can my father, who is a pig farmer like I am, visit me in the hospital without any protection measures whilst I have to be nursed in isolation?"

Affective/personal information needs concerned: Practical information needs (132 incidents), like:

- "Can I still have sex when infected with MRSA?", and "I am a teacher. Should I tell people at work that I am MRSA-positive?"
- Medical information needs (82 incidents), e.g., "Where can I obtain swabs?", "How should I take the antibiotics?"

Surprisingly, we found that the amount and type of information needs differed among the various types of MRSA-carriers: VA-MRSA carriers experienced relatively fewer information needs (84 out of 385 incidents) compared to CA- and HA-MRSA-carriers. VA-MRSA-carriers were served best with information on the hospital's MRSA policy. Carriers of CA-MRSA indicated that they needed both general and practical information, whereas HA-MRSA carriers had medical information needs.

The 385 incidents in which information was expressly required together represented 220 different questions related to MRSA. Since respondents indicated that answers to these questions would definitely help them to cope with MRSA in daily life, we

assumed that MRSA-carriers would benefit most from a question-oriented system conform the needs of care professionals [14]. Therefore, we decided to structure the system's content around the identified questions. The answers were based on standard MRSA-precautions, and were complemented by a medical microbiologist who was involved in the research project. The answers were directly communicated to the user in an instructional imperative style, e.g., "You should wash your hands frequently and cover your wounds." All answers were presented in a uniform way according to the following standardized structure: title, short description, comments, sources, and multimedia examples [25]. Users were allowed to decide upon the level of detail of the answer they wished to obtain, because next to the short answer, in-depth elaborative answers were provided, even in the form of sources (e.g., scientific literature, newspaper articles, links to websites for further reading, and explanations of the suggested topics). If possible, multimedia examples (e.g., instructional movies, pictures illustrating how to adequately apply personal protective equipment) were added as well.

Card sort and prototyping

The Card Sort methods resulted in eleven categories according to which the 220 questions resulting from the needs assessment could be structured. The categories identified by patients were: (1) MRSA in general; (2) Acquiring MRSA; (3) Testing; (4) Treatment; (5) In the hospital; (6) Hygiene and cleaning; (7) Contact with others; (8) Pregnancy and baby; (9) MRSA and my occupation; (10) the Netherlands and other countries, and (11) Contact. Together, categories 1 to 6 and 10 represented cognitive information needs, whereas categories 7 to 9 and 11 met affective/personal information needs. Furthermore, categories also served the needs of the various types of MRSA-carriers: VA-MRSA-carrier's information needs were met by category 5, CA-MRSA carriers' general and practical information needs were addressed in categories 1, 2, 6, 7, 8, 10, and 11, and the needs of HA-MRSA-carriers were answered in categories 3, 4, and 9.

Compared to general patient information materials, in which a more expert tone-of-voice is used, patients preferred a more practical approach of presenting information. Instead of using medical terms like "decontamination", MRSA-carriers indicated a high level of appreciation for terms that matched their expectations of medical information such as "Treatment" and "In the hospital". Based on the users' information retrieval preferences, the web-based system was equipped with two extra search functionalities next to the categorical search function based on the Card Sort Study: a Most Frequently Asked Questions search and an advanced question-answering system that enabled users to search for answers in their own vocabulary and language (Dutch, German). Feedback on the users' location on the system was provided by means of a breadcrumb trail on top of the page, to enable them to keep track of their location within the system to avoid "getting lost".

Furthermore, a self-learning functionality was incorporated in the web-based system. This function enabled the questions that were looked up most frequently to be ranked higher in the list when the users used the search engine or browsed through the categories. A dedicated content management system enabled the project-team to keep the system up-to-date by adding and deleting questions from patients at any time and at any location. This system also allowed the content to be continually updated based on the needs of patients (they can give feedback via a specific information button) and provided new insights into precautions for infection control, which is of vital importance because infection control policies are frequently subject to changes. In addition, the content management system enabled the project team to access log files that record general system activity. Questions that were not yet answered by the system could be easily added via the content management system.

We applied a research-based web design and usability guidelines when creating two non-working mock-up prototypes, taking into account the needs assessment results [25]. The mock-up prototypes each consisted of two pages (a homepage and a search page), and showed the system's lay-out and navigation. We asked patients to indicate their preference for one of the two prototypes, and choose the one that elicited the most positive reactions, such as "the convenient structure" (n=3), "the topic MRSA is presented clearly" (n=4), and "the trustworthiness suggested by the logos of the organizations taking part" (n=2). The content that resulted from the needs assessment, and the structure and lay-out that was generated by the design phase, were integrated into the first web-based working prototype. Figures 1 and 2 depict the final version of the web-based system. The system is free and accessible without the need to login. Users can choose between patient or HCW content (see Figure 1, numbers 1 and 2 respectively), to best fit their search. However, switching between the different types of content is possible.

Figure 1: MRSA-net home page

1=Entry button for content aimed at the general public (MRSA carriers/patients);
2=Entry button for content aimed at HCWs; 3=Button for the choice of Language (Dutch/German)

Figure 2: MRSA-net search page

1=Search engine; 2=Categories resulting from the Card Sort Study; 3=Most Frequently Asked Questions; 4=Breadcrumb trail; 5=Structured answer (title, short answer, comments, sources, multimedia examples, and related answers [not visible])

Usability Testing

A usability test of the first working-prototype was carried out. Eighteen (18) patients completed 110 concrete scenarios, of which 97 (88%) were successfully completed in an average of 131 seconds. According to the respondents, the high efficiency and

effectiveness with which they could retrieve information on the system was affected by the following factors:

- Action-oriented content: The evidence-based content was presented in a practical manner, which was highly appreciated by the respondents. Since the information on the system represented MRSA carriers' information needs as identified in the needs assessment, the information was perceived as very relevant, as shown by the following citation: *"If I would click on everything that I wanted to know more about, it would take me an hour and a half!"* Also, the information on the system created feelings of recognition ("patients like me") and reduced feelings of insecurity. For example: *"This information is very important. Had I known about this website at the time I was coping with MRSA, it would have solved so many unclear issues."* Respondents even stated that the system empowered them to take a proactive role in their own healthcare: *"I asked the healthcare worker to take screening cultures since I am living on a pig farm and therefore run a high risk of carrying MRSA. If I had not asked for it, the swabs would never have been taken."*
- User-generated search structure: In the majority of cases, the categories (as resulted from the Card Sort Task) were used to search for information to solve the scenarios. Patients appreciated the categorical search function, since it enabled them to orientate themselves towards the information that could be found on the system. Moreover, the fact that each category consisted of several relevant questions around the same topic inspired them to learn more about the theme. However, when patients wanted to formulate a specific query, the search engine was used. The combination of search strategies and continuously visible search functions caused the patients to perceive the system as very efficient: *"The good thing about this website is that it not only enables you to quickly look up a practical question in your own language, but it also gives you the chance to look around and read whatever you think is interesting."*
- Multimodal presentation of information (lay-out): The combination of several types of sources (news, websites, scientific articles) and modalities (videos, pictures) was valued positively. It facilitated the ease with which information was understood and could be applied to daily practice. Alongside the web-based systems' benefits, we detected several flaws. First, it appeared that the information was not tailored optimally to the specific information needs of the three groups of MRSA-carriers. The VA-MRSA carriers, in particular, who experienced the lowest information needs during the needs assessment, believed that the information did not adequately fit their needs. They felt that most practical information was addressed to CA- and HA-MRSA carriers, whereas VA-MRSA indicated that they also wanted to know how to cope with MRSA in their daily (work) routine. In response to these problems, one category, "Animals and pig farms", was added. Secondly, the information structure did not function optimally since respondents did not use the cross-links between questions.

They were not aware of this function because they hardly ever scrolled down the page. We resolved these issues prior to the web-based system's official launch.

Summative evaluations

Since its launch in February 2008, MRSA-net has achieved increasing numbers of monthly visitors. By the end of 2010 it has stabilized at approximately 11,000 unique users of the system per month (both patient/general public and HCW-targeted content). Of these users, 38.7% visited Dutch content, 59.6% visited German content, and 1.7% viewed both types within one visit. Users entered MRSA-net directly using the URL or a link 35,887 times (41%) in 2008; 81,806 times (30%) in 2009; and 107,789 times (30%) in 2010. However, most often users are referred to MRSA-net by an internet-search-engine: 51,519 times (59%) in 2008 (of which 84% via Google); 194,062 times (70%) in 2009 (of which 96% via Google); and 248,518 times (70%) in 2010 (of which 98% via Google). This result is in line with the observation that users often entered MRSA-net on an answer page, as opposed to the intended route via the homepage: 23,187 times in 2008, 85,545 times in 2009, and 118,978 times in 2010.

Another result from the summative evaluation that demands our attention is the considerable number of visits that lasted more than 5 minutes and in some cases up to 30 minutes which seems rather long; 6,795 visits (14%) in 2008, 19,914 visits (13%) in 2009, and 30,617 visits (16%) in 2010. During these visits users accessed several (answer) pages. This may indicate that they either had various information needs, or that they could not easily find the information they needed.

To illustrate how users search for information in the patient/general public section of the system, we performed preliminary analyses on the search methods users applied once or more during the space of one visit. Figure 3 illustrates these numbers; the answer pages were accessed directly via an external referral 43,055 times (NL) and 61,374 times (GER), thus via a direct link or search engine. Related questions that are displayed below the answers were used 22,724 times (NL) and 29,866 times (GER) to access answer pages. Further, Figure 3 shows that the categories, (no. 2 in Figure 2) were used 16,023 times (NL), and 25,105 times (GER), respectively, to find information. The Frequently Asked Questions, number 3 in Figure 2, were used 3,991 times (NL), and 12,152 times (GER), respectively. An open search via MRSA-net's search engine, number 1 in Figure 2, led patients 958 times (NL) and 2,165 times (GER) to the answer pages. In 3,379 (NL) and 4,639 (GER) cases, no search was carried out and no answer was viewed. Usually, these users looked at one or more news messages.

Figure 3: Frequency of search methods used within a visit, in numbers.

Figure 4: Categories of the system that were used; in percentages.

Figure 4 shows the categories that were used for searching information. Between July 2008 and the end of 2010, the categories on the patient-targeted content of the system were used 101,024 times (NL), and 163,547 times (GER). As depicted in Figure 4, the most frequently used categories are 'MRSA in general'; 20% (NL), 20% (GER) and 'Acquiring

MRSA'; 17% (NL), 13% (GER). Figure 4 further shows that the categories used least often are 'The Netherlands and other countries/Germany; 2% (NL), 2% (GER), and 'eContact with a hygiene expert; 1% (NL), n/a (GER).

A first screening of the data further showed that a number of users switch between HCW and patient/general public content within one visit; in 16,842 (6%) visits both content types were accessed. This percentage seems quite low, but considering the fact that a lot of users visit only one page, it can be concluded that a considerable percentage of the users who visit more pages, switch between the content types. This indicates that information aimed at patients and the general public insufficiently addresses public concerns, that patients need more professional information, or that the patients (and members of the general public) and HCWs have similar information needs. In other words, tailoring information towards patients or HCWs is, to some extent, artificial.

Discussion

Since the advent of the Web, the practice of making information available to patients has gone through a paradigm shift. The healthcare provider is no longer the sole gatekeeper of medical knowledge. Patients and members of the general public have more and more recent medical information at their fingertips, and they have more time to read it than their health providers [26]. However, the design of most online patient information and education systems relies primarily on conventional wisdom among experts, rather than on evaluation by its intended users. It is not surprising, therefore, that patients often miss the point and become confused; a situation which is often further compounded by their inability to determine the reliability of the information source.

The participatory development process as described in this chapter proved effective for attuning the information needs to the patients' demands and expectations. This study provided us with a user-centered system that enables MRSA-carriers to search efficiently and effectively for practical information, which contributes to the ease of coping with an infectious disease in daily life. Because MRSA-carriers indicated that their information needs were often of a practical nature, we tried to couple information on the web-based communication system to the relevant activity. By ensuring that the information is there whenever, and in whichever format the MRSA-carriers want it, we anticipated that good quality information forms the basis for MRSA-carriers to make informed choices about their actions. This fits the concept of Information Therapy [27].

In addition, the internet enables tailored communication to different target groups, which might be beneficial for the three different types of MRSA-carriers (VA-, CA-, and HA-MRSA) that we involved in our study. This study showed that information needs depended on the type of MRSA people carried. By considering the different information needs of various patient groups, the information has the maximum impact on knowledge,

attitudes, and subsequent safety behaviour [27]. By including relevant dynamic and visual media, this effect might be enlarged. The content appeared to be of value for a variety of users, including HCWs, patients, and the general public given, This is supported by the fact that the system is used frequently and ranks third when searching for MRSA with Google (in Dutch), without applying (paid) search engine optimization. Besides, the web-based system enables self-management, given the fact that the eContact category (consult a hygiene expert if you have any questions) was hardly used.

As our results show, internet search engines, mainly Google, are used to find the system and its contents. “Googling” is thus an important factor for locating or finding a web-based communication system. Google might have replaced the on-site search engine that was hardly ever used because this Googling-strategy is more in line with the users’ searching habits. Internet search engines lead many users to MRSA-net, and using search engines is common when searching for health-related information [28-29]. Therefore, we must ensure that the health information sources we develop (including MRSA-net) are found, and will continue to be found, via these search engines. In addition, such direct access should not result in missing important explanatory information because the homepage is skipped. Thus, on-site search engines seem irrelevant when the information is sufficiently indexed by internet search engines. Having a smart navigation structure would seem to be more relevant; one that offers suggestions to users and assists users who spend more time on the site when searching for information. This view is supported by the finding that the “related-question” search method (Figure 3) was the second most frequently applied method.

Although this research project showed many benefits of user-involvement, it also revealed some weaknesses. These concerned the voluntary basis on which MRSA-carriers participated that might have biased the results, together with the small sample size, which possibly impeded generalization of the results to other contexts. To overcome these limitations, we carried out a summative evaluation via an analysis of the log files to identify whether the usage (questions asked) represents the content structure of the current system. Ongoing analysis will show if new categories emerge, possibly due to the aforementioned selection bias and/or a change in MRSA policy (because of the increase in outbreaks in public health).

Another limitation is that the log files are not reducible to patients with MRSA or members of the general public, due to the freely accessible system where no login is needed for reasons of expanding accessibility without restrictions. The distinction between members of the general public or HCWs may suffer from a similar bias because this separation is based on the self-chosen content type (HCW or member of the general public, numbers 1 and 2 in Figure 1) that users entered. Thus, we cannot be sure that the users who entered HCW content are indeed HCWs. Also, since many users entered the answer pages directly via Google referral, which requires no user type at all to be selected, we can only

determine the type of content they viewed, not who they are (HCW/patient). This tailoring of content to user type (HCW or patient/public) may have become redundant. The distinction between HCW and patient information needs may fade in time, caused by the accessibility of medical information on the internet to patients, members of the general public and HCWs. In any case, the summative evaluation shows the importance of a participatory development approach of a web-based communication system and the need for an advanced navigation system and adaptive and flexible content management system.

Future research to optimize the MRSA information system

To gain more insights into the actual use of the system, as opposed to intended system use, we plan to carry out the following research activities.

Optimizing the content and the system:

- Validation of the content-structure through log file analysis. By first analyzing which strategy is used most often to access answers on MRSA-net, the rationale of providing a topic structure can be validated or refuted.
- Combining frequencies of topics and answers accessed on MRSA-net with a content analysis through card sorting of questions posed on the system's search engine. This enables us to confirm whether the categories fulfill the users' information needs, whether there are unused categories, or whether new categories have emerged that are currently not supported by the topic structure and MRSA-net content. This enables us to validate the user-centered methods that were used to create the structure. It is important to keep the content up-to-date, according to users' information needs. The information needs that become apparent from real-life searching practice on MRSA-net, as opposed to the research setting, indicates whether the methods used (scenario-based testing, card sorting) have resulted in good structures.
- Data-mining will be applied to the log files to further search for use patterns and provide a so-called digital fingerprint of the MRSA-net [24, 30]. This information will then be used to find out how the interface needs to be designed and how it should function to serve all users. Since preliminary results show that users search for information in their own domain (public content) as well as professional content, we need to conduct more research into the differentiation of users (professionals and members of the general public) to best serve their information needs and facilitate searching. Possible differences in search behaviour that become evident from the mining techniques will enable us to automatically fine-tune content to users.
- To accommodate different users with different search or use strategies we think that, besides studying current user actions, we need to continuously use this data to optimize the question and answering-system. Based on previous user activity, the system can suggest content that may be of interest and such a strategy seems to fit

with our observation that except from (short) Google-referred visits, during visits convenient searching (related questions and FAQ) is applied often. Since patients are often unable to express their need for a specific type of information in a single, self-contained query within the medical domain [31], the search system will allow patients to ask for clarification, make corrections to the system's interpretation of utterances, and ask follow-up questions. Search engines that help users specify their query already show promising results [32]. Consequently, tailoring information and eliciting user input will be the focus of our future research activities.

Future research to develop other web-based communication systems

Although MRSA-net served as a case study, the methodology can also be used to develop patient education about all types of infectious diseases, such as ESBL, HIV, hepatitis, etc. and reducing the use of antibiotics to prevent resistance. One of the main findings of this study concerns the usefulness of the methods for participatory development. It can be concluded from this study that the methods used for content design (Card Sort) are valuable because after two years of usage most categories remained intact. This means that the Card Sort method is a useful tool for fine-tuning the information structure to the mental models of patients/members of the general public [14].

However, the results made clear that a participatory development approach involving the end-users is beneficial but not sufficient for the implementation of a web-based information system in public healthcare. Experts (e.g., hygienists) and policy-makers (e.g., National Institute for Public Health and the Environment) initially expressed their doubts about using the system because they were not consulted in the development process. However, after we explained to them that the content does not conflict with the protocols or standards about infection control and after they started using the system, they became staunch advocates of it. From other studies about developing technologies for the healthcare system, it appeared that stakeholder engagement is important for implementing technologies in healthcare [12].

At the moment, the high popularity of the system in the Netherlands as well as in Germany (an award was given to it for being the best cross-border project) indicates that it has legitimacy in the field of infection control. This requires an extension of the system to a public health service, for (local) Public Health Services and primary healthcare facilities (GPs). To incorporate the web-based system in the healthcare organization, for example in Public Health Services or in primary healthcare we have to involve stakeholders other than the primary end-users in order to elicit commitment and trust in a system that has not been developed by the experts themselves. Nijland [31] also demonstrated that stakeholder involvement appeared to be important in the development of sustainable eHealth technologies that are accessible, acceptable and affordable.

This is of interest for future research aimed at “translating” expert-based infection control information into communication systems for the general public and HCWs to help them understand treatment and improve self-management. This is the subject of future research, EurSafety Health Net; the development of an online communication platform to support all stakeholders (patients, payers, policy-makers, care providers) in the care process and to increase cross-border patient safety (<http://www.antibioticstewardship.nl>).

In our future research, we will carry out a multi-stakeholder assessment to identify the needs to upscale the system to a web-based platform for cross-border patient safety. From other research we know there is a need for a multi-stakeholder, broader-than-the-end-user perspective to ensure that technologies will be implemented in practice [33]. Stakeholder-testing will be performed throughout the development process to a) get a thorough understanding of the context of infection control and patient safety, b) elicit stakeholder needs and values, c) co-create content for the platform. The stakeholders that will be involved in the development and design phases include experts (e.g., National Institute for Public Health and the Environment, European Centre for Disease Prevention and Control), patients, healthcare workers, and the public. Thus, stemming from the results of MRSA-net research, we will involve end-users as well as other stakeholders in the refinement and upscaling of the current web-based system to a patient safety platform for infectious disease management.

To support the participatory development approach, we will use a roadmap for involving users and stakeholders [34]. Figure 5 shows the CeHRes (center for eHealth Research) roadmap [34]. This roadmap integrates Human-Centered Design with business modelling activities to ensure that the development is guided by stakeholder needs and values and can be implemented successfully. We have learned that implementation and evaluation are continuous research activities that start at the beginning of the development process and involve the participation of end-users and other stakeholders. The roadmap is based on eHealth research and a literature review about current models for participatory development.

Figure 5: CeHRes roadmap

Conclusion

To close, the most important conclusions of this study are summarized below:

- Participatory development involving end-users resulted in a promising web-based communication system for health promotion, fine-tuned to users' needs and mental models about health communication. Intended users were content with the presentation and scope of information. The system appeared to be frequently used in both the Netherlands and Germany.
- Participation of users in a development process requires a rethink about the development of eHealth technologies. Instead of an expert-driven approach, the development of eHealth technologies should be considered as a process of co-creation with the users. Strategies are needed based on empirical studies to decide how, when and with what aims users should participate and what the benefits are, given the required time and cost of user involvement.
- The participation of key-stakeholders is needed to ensure the implementation of eHealth in different care settings (public health, primary, or secondary care).
- Development should be accompanied by the continuous evaluation of, and ongoing adjustments to, the way the information is presented based on users' and stakeholders' needs and goals in order to accommodate them optimally. The CeHRes roadmap that was presented and the accompanying instruments will be used in several research projects to determine its value for practice, policy and research. Therefore, we will present it as an eHealthwiki tool [35].

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Chapter 3. Evaluation of the Card Sort method

This chapter is based on:

Wentzel, J., Müller, F., Beerlage-de Jong, N., & van Gemert-Pijnen, J. (in review). Card sorting to evaluate the robustness of the information architecture of a protocol website.

In review in the *International Journal of Medical Informatics*, a revision was submitted on 2 September 2015.

Abstract

Objectives: Applying Human Centered Design to ensure a match between user and technology is of paramount importance in healthcare contexts. Card sorting is a method that enables researchers and developers to attune the information structure to users' mental models and information needs. In this study we evaluate the card-sort driven structure of a protocol website (MRSA-net, a website with information on the Methicillin-resistant *Staphylococcus Aureus* bacterium). The website contains information aimed specifically at health care workers and the general public, and is available in German and in Dutch language. We evaluate the card sort method that led to the website main categories after long-term website usage.

Methods: An open card sort study was conducted. As input for the cards, we used on-site search queries as they were entered on the MRSA-net website (after one year of website use). The resulting stacks of 100 cards were sorted in individual sessions by 18 German and 10 Dutch Health care workers, and 10 German and 10 Dutch members of the general public into groups that were meaningful to the participants. The participants also provided a label for each group they had formed. The resulting sorts were analyzed using cluster analysis, to check which cards were placed together in one group and thereby categorizing the sample of search queries. In addition, group labels were qualitatively analyzed to identify the participants' mental models corresponding to the domain.

Results: Cluster analysis revealed new themes emerging from the search query samples that were used in this study such as financial issues and consequences for the patient. Even though information on these topics may be present on the website, these are not prominent topics that are covered in the menu structure. In addition, the label analysis shows that 7 of a total of 44 MRSA-net categories were not reproduced by the participants. However, the overall majority of categories was reproduced and thus still corresponds to the target group's mental models. Additional information and categories did emerge and differences between user groups (regarding nationality or professional status) were found.

Conclusions: This study shows that the card sorts performed to create MRSA-net resulted in overall long-lasting structure and categories. New categories were identified as well, indicating additional information needs emerged. Therefore, evaluating website structure should be a recurrent activity. Card sorting with ecological data as input for the cards is useful for identifying changes in user needs and mental models. The combination of quantitative (cluster) analysis and qualitative (label) analysis renders important insights into additional information that is needed and the target group's view on the domain and belonging (to them relevant) themes. The results show differences between the four user groups in their sorts, which can mostly be explained by the groups' backgrounds (nationality or professional status). This finding confirms the need for tailoring information as was done when creating the MRSA-net website.

Introduction

Picture a medical protocol database, designed to enable health care workers to find relevant protocols for providing safe care to infectious patients, that only retrieves search results for queries that exactly match the indexed expert-driven terms. For example, a nurse lacking the medical expert jargon will be unable to find instructions when searching for “how to wear a gown”, instead of “personal protective equipment protocol”. This leads to frustration, and possibly dangerous situations. In healthcare, as well as in other professional or personal settings, examples like this, i.e., technology that is ill-fitted to the tasks or needs of the users it aims to support, are abundant. As a reaction, developers and designers aim to put the intended end user central during development by applying human-centered design (HCD). This design approach, promotes taking on a user perspective to ensure that technology design fits with its users’ abilities and preferences, and thereby leads to a better usability and effective use [1]. Involving users, as well as other stakeholders, in development and testing technology design (or even, co-create), is helpful to increase this human-technology match [2]. Besides a pleasurable user experience, leading to recurrent use (e.g., website visits), HCD can be of paramount importance to ensure that the target group can use the technology the way it was intended, in everyday life or during specific tasks. HCD can contribute to acceptance and uptake of a technology [1]. Therefore, even though involving the target group in the development phase costs time, effort, and money, doing so seems worth it. Especially in health care situations, costs to involve users in development may be high. This is due to the specific health care setting, where health care workers (HCWs) are primarily occupied with providing care and may lack time to be involved [3]. Likewise, it may be difficult to involve patients, due to their health issues. Thus, getting the technology right at once is important, especially in health care.

Card sorting

One of the key assumptions of HCD, and motivations for applying it, is that it leads to a better fit between human and technology, a better usability, and information technology that is supportive of user tasks [1, 2]. Methods that are applied to ensure a match between target group, context, and technology, include ecological studies (e.g., observations). In addition, to gain a good understanding of the target group, interviews/questionnaires can be applied as a more interactive method of user-need inquiry. Further, co-design sessions, involving (rapid) prototyping, and prototype evaluations help to create appealing [1] designs. Card sorting is a method that is often used to create an effective information structure, which matches the mental models of the target group and enables them to find, interpret and apply information easily [1, 4]. In this method, information excerpts representing the content of the website (or other medium) is printed onto cards (digital or paper). Participants representing the target group are asked to sort the cards into groups that are meaningful to them. Either a predefined set of groups can be used (closed-card

sort), or participants are fully free to create and name as many groups as they think are necessary (open-card sort). These sorts can be analyzed to create clusters of information which serve as a basis to structure the website [5, 4]. In this approach, the frequency with which two cards are placed in the same category by the participants, as well as the similarity between group names (labels) can be of interest to establish the preferred structure and categorization of the information. Card-sorting is often applied as a method for short-term evaluation of website architecture [6, 7] and not much is known about the extent to which card-sort results lead to long-lasting information architectures. By evaluating a website with medical protocol-based information, we search to gain insight into card-sort driven information structure on a long-term basis.

3

A protocol website

A mismatch between user (target group) information needs and available information resources is problematic, especially in care settings where Methicillin-resistant *Staphylococcus Aureus* (MRSA) is prevalent. Patients carrying or infected with this drug-resistant bacterium require highly protocolized care, often involving isolation measures, specialized medication, and stringent protective and disinfection precautions. It is important that HCWs, the patient, and others in the vicinity of the patient adhere to these measures. This is needed to prevent the spread of this dangerous pathogen within a care institution (and community) and to cure the patient. MRSA prevalence may vary between countries and regions. Therefore, cross-border mobility of patients and HCWs who seek or provide care may enable potential pathogens such as MRSA to spread and cause outbreaks. As a consequence, appropriately dealing with MRSA infection risks is crucial. To achieve this, the aim of the cross-border European project MRSA-net was to improve cross-border patient safety, among other strategies by improving the practical applicability of (information in) MRSA protocols, for HCWs and the general public [8].

Earlier research showed that both the general public (including patients), as well as HCWs have information needs regarding MRSA that were not being met [9-11]. Information concerning MRSA is often highly expert-driven. This results in patients having difficulties understanding why certain procedures are necessary and an information supply that often does not match their actual (daily-live driven) information needs. In addition, HCWs encounter difficulties when applying MRSA protocols in their daily care practice. To accommodate the information needs regarding MRSA of both the general public (including patients) and HCWs, and support better adherence to MRSA prevention and control measures, an information website, www.MRSA-net.nl, was developed [11].

For the development of MRSA-net, various methods were applied while continuously involving the target group in the design process [11]. The website offers, both in German and in Dutch, protocol-based information. This information is structured and formulated to match the target groups' information needs. The MRSA-net structure was

derived from card-sort studies and based on user evaluations. The design and presentation of information is matched to user expectations and preferences. This includes clear instructions (written and/or videos) on how to perform certain infection control measures, and background explanations.

After entering the website's homepage, users choose between HCW and public content (see Fig. 1). Hereafter, they arrive at an overview page tailored to their choice. This displays the information structure as was derived from the development process, including 12 (public) or 10 (HCW) main categories. These main categories remain visible when viewing target content (see Fig. 2). Also, an open search field and frequently asked questions can be accessed from here. MRSA-net users can access information on a wide range of topics, including information on treatment, protective measures, and other protocolized actions. In addition, it provides information on matters concerning HCW's or patients' personal lives (safety, risks of contamination), overall prevalence and sources of infection.

3

Figure 1. MRSA-net homepage

At the home page (www.mrsa-net.nl/) a choice between public (1) and HCW (2) content, and German and Dutch (3) language can be made.

Figure 2. Example of a MRSA-net target page

Users search for information in the open search field (1), choose an information topic from the categories (2), or scroll through the frequently asked questions (3). A breadcrumb trail (4) aids orientation, and target content (5) consists of multimedia and text, presented in a question-answer fashion.

Study aim

In this study, we investigate to what extent the user-driven website MRSA-net actually complies with user information needs, over one year after its release. More specifically, we aim to evaluate card-sorting as a method for establishing a website structure in concordance with the target group's mental models. By using ecological data (logged search queries), we validate the card-sort-driven design process on a long-term basis involving all four (intended) MRSA-net user groups. This enables us to identify possible flaws in the information structure, based on actual use.

Method

Open card sorts were conducted with German and Dutch HCWs (target group of MRSA-net professional content), and German and Dutch members of the general public (target group of MRSA-net public content).

Materials

For the cards used in the card sort sessions, we identified the search queries (words and or sentences) that users applied on MRSA-net's internal search engine from the website's log data. These data represent user information needs, which may or may not have been met by the MRSA-net content. A random sample of 10% of all search engine entries was taken

from the logged search words in the timeframe January-April 2009 (N=971 and N=694 for German and Dutch searches, respectively). In this period, log data showed a stabilization of use, since the website's release. Words and sentences in these entries that overlapped, were difficult to interpret, or were unrelated to MRSA (out of context) were removed. For example: *MRSA symptoms* and *symptoms MRSA* appear as two different search phrases, and were merged in our search phrase sample. Also, a search entry such as *Outdoors* (in Dutch: buitenlucht), is considered too vague to interpret and was removed from the sample. In addition, evident typos were corrected to improve readability. In case of removal of search phrases from the sample due to aforementioned reasons, an additional random sample was drawn and checked until a sample of 100 words/phrases was created. This procedure was performed for all four categories of content (Dutch/German, public/HCW), resulting in four sets of 100 words/phrases that were printed onto paper cards. The materials that were used in this study differ from the card sort materials that were used for the initial creation of MRSA-net, in that the current study uses ecological input (search words representing actual information needs during website use), while in the card sort study that guided MRSA-net's design, cards were used that were created based on users' reactions to and problems with using MRSA protocols.

Participants

For all four groups (Dutch/German, public/HCW), convenience samples were used: a total of 20 members of the general public, and 28 HCWs (nurses, hygienists, residents, physicians) participated. Among the participants are 15 men and 33 women. The participants' mean age is 34. The Dutch public, Dutch HCW and German public groups consisted of 10 participants and the German HCW group consisted of 18 participants. This about in line with participant numbers mentioned to be required for card sort studies in formative design phases [12]. Participant characteristics per user group are displayed in Table 1. The HCWs were recruited via local hospitals in the Netherlands and Germany, general public participants were recruited via the researchers' personal network. Prior to participation, every participant was instructed about the study and signed an informed consent form. Participants were free to withdraw from the study at any moment.

Table 1. Participant characteristics per participant group

	Dutch	German
HCW	N = 10 Mean age (31) Male 1 (10%)	N = 18 Mean age (39) Male 8 (44%)
Public	N = 10 Mean age 30 Male 3 (30%)	N = 10 Mean age 34 Male 3 (30%)

Procedure

In individual sessions (about 45 minutes), participants were given a stack of 100 cards with the MRSA-related words/phrases. They were instructed to sort the cards into groups that were meaningful to them. Also, they were asked to provide a label for each of the groups they created in their own words by writing the group label down on a blank label card. Participants could create as many groups as they deemed necessary. After the participant had finished, the researcher wrote down all group labels and cards per group.

Analysis

Card sort results were analyzed based on cluster analysis. In this analysis, patterns of cards that are related to each other according to participants' mental models are identified by analyzing how often they are placed together in one category. The participants' card sorts were inserted in a spreadsheet, adapted from [13], and applied before [14]. With this sheet, individual sorts were compared and item correlations calculated. Based on the resulting item correlation matrix, a Hierarchical Cluster Analysis (intervals based on squared Euclidian distance) was performed using IBM SPSS Statistics v.20. Clusters ranging from 2 to 12 were calculated. For each subgroup (Dutch/German, public/HCW) the amount of clusters that would be used for further evaluation was chosen based on interpretation of the agreement in clusters (agreement percentages ranging from >75% - high; 50%-75% - acceptable; 25%-50% - moderate; to <25% - weak) and their content. Two researchers independently provided each cluster with a name, based on its content. Concordance between these two researchers was assessed and differences were discussed until agreement was reached.

In addition to the cluster analysis, the labels participants provided for each of the groups they created were analyzed and compared to the current website categories. First, two researchers independently summarized and standardized all unique labels that were created by the participants, based on overlap of meaning. E.g., the labels *MRSA in general* and *General information* were coded into *General information* and *MRSA Europe* and *Where does MRSA occur?* were coded into the category *Prevalence*. The researchers used current MRSA-net categories for standardization, or created a new category when no existing one sufficed. All differences in coding were discussed until full agreement on label standardization was reached. Where necessary in the analyses, one of the native German speaking researchers checked interpretations made by the non-native German speaking researchers.

Results

Per group cluster analysis

On item level, cluster analysis provides insight into which items are placed together in a group and are thus (content-wise) linked to each other. The clusters were named by two independent researchers, producing an instant agreement regarding the name for 30 of the 43 clusters that were created (70%). The remaining cluster names (for which there was no initial agreement) were discussed until agreement was reached. The resulting cluster names are displayed in Table II and III.

Some cards are more uniformly placed in one cluster than others. This is illustrated by the correlation matrix, (partially) depicted in Figure 3, which shows the item correlations of Dutch HCW sorts. In this matrix, a darker cell color visually represents a stronger correlation percentage, and it shows that some items are also paired with items outside their cluster. For example, item 12 ("Alertness in the hospital"), is placed in the cluster *In the hospital*. However, this item was also quite often placed in one group with items belonging to the *Prevention (of spread)* cluster; 50% of the participants placed it with item 92 ("What about isolation of geriatric patients: confused, disoriented"), and 40% of the participants placed item 12 with item 82 ("To close a ward"), item 58 ("A closed ward"), or item 18 ("Tourniquet for MRSA patient"), as can be seen in Figure 3. In the supplementary files the correlation matrices of all four participant groups (Dutch/German, public/HCW) are given. In the following two sections we report the resulting clusters per group.

Card no	Card name	average	12	41	67	80	86	3	9	14	18	21	24	27	32	58	60	72	82	92	99	4	45	52	11	57	62
	12 In ziekenhuis alk	56 x		60	40	60	50	20	20	10	40	10	30	30	10	40	30	30	40	50	20	10	0	0	40	20	20
41	MRSA op de ok	60 x		40	80	60		20	0	20	20	20	50	20	0	30	30	10	40	30	20	10	0	0	20	30	20
67	Polikliniek bezoek en MRSA	40	40	x	40	50		10	0	20	10	20	40	10	10	30	10	20	20	20	10	20	10	10	30	30	10
80	Operatiekamer	60	80	40	x	50		20	10	20	20	0	40	10	20	40	10	20	20	20	20	10	0	0	20	10	20
86	Operatiekwartier	50	60	50	80	x		20	10	20	20	0	40	10	20	40	10	30	20	10	20	10	0	0	20	10	20
3	Schoonmaken k	53	20	20	10	20	20	x	50	80	70	40	50	60	70	60	80	60	80	50	90	0	0	0	20	0	10
9	Protocollen	20	0	0	10	10		50	x	40	60	30	30	40	50	30	50	60	50	30	60	0	10	0	20	0	10
14	Isolatie algemeen	10	20	20	20	20	80	40	x	60	50	50	60	70	50	70	50	70	50	80	10	10	10	20	40	10	
18	Stuwband bij MRSA patiënt	40	20	10	20	20	70	60	60	x	40	40	70	60	50	80	70	80	60	70	0	0	0	60	40	40	
21	Beschermingsmaatregelen	10	20	20	0	0	40	30	50	40	x	30	40	40	20	50	20	50	20	40	10	10	10	20	30	10	
24	Opnamebeleid	30	50	40	40	40	50	30	50	40	30	x	30	30	30	50	30	60	30	50	10	10	10	20	40	10	
27	Welke isolatiemaatregel nee	30	20	10	10	10	60	40	60	70	40	30	x	40	60	70	50	70	60	60	10	10	10	20	40	10	
32	Virobuster	10	0	10	20	20	70	50	70	60	40	30	40	x	40	50	50	50	30	60	10	10	10	20	20	20	
58	gesloten afdeling	40	30	30	40	40	60	30	50	50	20	30	60	40	x	50	40	60	30	60	10	0	0	30	20	10	
60	Opheffen beschermende ma	30	30	10	10	10	80	50	70	80	50	50	70	50	50	x	60	90	60	80	0	0	0	40	40	20	
72	Zorghandelingen	30	10	20	20	30	60	60	50	70	20	30	50	50	40	60	x	60	50	60	0	0	0	50	30	30	
82	afdeling sluiten	40	40	20	20	20	80	50	70	80	50	60	70	50	60	90	60	x	60	80	0	0	0	40	40	20	
92	Wat met isolatie bij geriatri	50	30	20	20	10	50	30	50	60	20	30	60	30	60	50	60	50	x	50	0	0	0	40	30	20	
99	afmeting sluis	20	20	10	20	20	90	60	80	70	40	50	60	60	60	80	60	80	50	x	0	0	0	30	30	10	
4	MRSA Europa	63	10	10	20	10	10	0	0	10	0	10	0	0	10	10	0	0	0	0	0	x	50	50	0	10	10
45	Prevalentie	0	0	10	0	0	0	10	10	0	10	0	0	0	10	0	0	0	0	0	50	x	90	0	10	10	
52	Prevalentie MRSA Nederlan	0	0	10	0	0	0	0	10	0	10	0	10	0	10	0	0	0	0	0	50	90	x	0	10	10	
11	Roistoel	53	40	20	30	20	30	30	20	20	60	20	10	40	20	30	40	50	40	40	30	0	0	0	x	60	60
57	MRSA en activiteiten	20	30	30	10	20	30	10	0	40	40	30	20	40	20	20	40	30	40	30	30	10	10	10	60	x	40
62	overleden	20	20	10	20	30	10	10	10	40	10	10	20	20	10	20	30	20	20	10	10	10	10	60	40	x	

Figure 3. Item x item correlation matrix (partial)

Cluster analysis – HCW sorts

In the Dutch sorts, the strong clusters (average correlation percentage >75) *Animals* (95%) and *Diagnostics/culturing* (94%) were identified (see Table II). The only weak cluster

(average correlation percentage <25) that emerged from the Dutch data is *Financial and diagnostics* (23%). No strong or weak clusters emerged from the German HCW data. The highest average correlations in the German sorts are acceptable (average correlation percentage 50-75), and include the groups *Other pathogens* (70%), and *Sources of infection/reservoirs* (62%). The lowest average correlations in the German sorts are moderate (average correlation percentage 25-50) and include *Prevalence and epidemiology* (38%) and *Transport and Outside the hospital* (34%).

Even though the two groups (German and Dutch HCWs) sorted different samples of cards (one German and one Dutch random sample of search queries was used), some overlap in clusters is present between both languages: topics addressing diagnostics, prevalence and treatment or medication surface in both analyses (see Table II).

Table II. HCW sorts cluster analysis results

Language	Cluster name	Average correlation percentage* (amount of cards)
NL	Animals	95 (4)
NL	Diagnostics/culturing [^]	94 (5)
NL	Prevalence [^]	63 (3)
NL	In the hospital	56 (5)
NL	(care) outside of the hospital	54 (10)
NL	Antibiotics/medication [^]	54 (6)
NL	Other	53 (3)
NL	Prevention (of spread)	53 (14)
NL	Description and contamination	49 (31)
NL	Symptoms, work, and pregnancy	41 (13)
NL	Financial and diagnostics	23 (6)
GER	Other pathogens	70 (3)
GER	Sources of infection/reservoirs	62 (9)
GER	Protective measures/disinfection	54 (20)
GER	Patients who are at risk	54 (3)
GER	Antibiotics/treatment [^]	53 (6)
GER	Contamination, disease progression	53 (15)
GER	Diagnostics [^]	45 (8)
GER	HCW obligations, legal issues	44 (11)
GER	Prevalence and epidemiology [^]	38 (12)
GER	Transport and outside the hospital	34 (13)

*Average of all item-item correlation percentages in this group

[^]Similar clusters (topics) were found in both languages

Cluster analysis – Public sorts

The general public's sorts resulted in no strong clusters (average correlation percentage >75) in the Dutch and German sample (see Table III). Acceptable agreement (average correlation percentage 50-75) was found in three of the Dutch clusters: *Risk groups* (63%), *Profession* (61%) and *Co-morbidity, symptoms* (53%). The other clusters have moderate

agreement (average correlation percentage 25-50), ranging from the highest moderate average correlation in the cluster *Patient care* (for HCW) (49%) to *Risk of contamination* (30%) as lowest average correlation percentage. German highest agreement clusters are acceptable, with *Symptoms* (67%) and *Description of MRSA* (58%). One weak cluster emerged in the German data; *Risk factors* (22%), the other clusters have moderate average correlation percentages. Overlap between German and Dutch general public clusters include clusters addressing symptoms, treatment, a description of MRSA, consequences for the patient, and risks of contamination.

Table III. Public sorts cluster analysis results

Language	Cluster name	Average correlation percentage* (amount of cards)
NL	Risk groups	63 (8)
NL	Profession	61 (6)
NL	Co-morbidity, symptoms [^]	53 (17)
NL	Patient care (for HCW)	49 (5)
NL	Treatment [^]	47 (12)
NL	General information, description [^]	44 (23)
NL	Consequences for the patient [^]	43 (7)
NL	Financial and contact	42 (7)
NL	Prevention	42 (8)
NL	Risk of contamination [^]	30 (6)
GER	Symptoms [^]	67 (3)
GER	Description of MRSA [^]	58 (10)
GER	Pregnancy, children, the elderly	47 (9)
GER	Prevalence and epidemiology	45 (4)
GER	Treatment [^]	41 (17)
GER	Protection	40 (12)
GER	Source and risk of contamination [^]	35 (6)
GER	Obligations and costs	35 (6)
GER	Consequences for patient [^]	33 (4)
GER	Reservoirs in the body	30 (3)
GER	MRSA in daily life	28 (17)
GER	Risk factors [^]	22 (4)

*Average of all item-item correlation percentages in this group

[^]Similar clusters (topics) were found in both languages

Label analysis

Participants provided labels for the groups they created. Initial analysis resulted in an agreement on 62% of German HCW and 70% of German public label standardizations between both researchers. Regarding the Dutch label data, the initial analysis (standardization) resulted in an agreement of 63% (HCW) and 62% (Public) between the two independent researchers. The non-agreed upon label standardizations were further discussed until agreement was reached, resulting in the labels as are presented in the following two sections.

HCW labels

The summary of the original (participant) labels and comparison to MRSA-net category shows that nearly all MRSA-net categories were used as a label for a self-created group in the card sort by one or more participants (see Table IV). Especially the categories *General information*, *Treatment* and *Culturing* were often used with 56% to 90% of all participants creating these categories. *Admission to the hospital*, *Transport* and *Discharge from the hospital* were less often recognized; 0% to 40% of the participants used one or more of these categories as a label for one or more of their groups, and few cards are placed in them (0-19), as can be seen in Table IV.

Table IV. HCW MRSA-net resembling group labels

MRSA-net categories	Language*	% that created this category (n)	Amount of (unique) cards placed in this category
General information	NL	90 (9)	78
	DE	67 (12)	60
Treatment	NL	80 (8)	14
	DE	78 (14)	63
Culturing	NL	80 (8)	17
	DE	56 (10)	33
Protective measures	NL	30 (3)	20
	DE	67 (12)	72
When I have MRSA myself	NL	60 (6)	39
	DE	22 (4)	11
Desinfection measures	NL	10 (1)	4
	DE	61 (11)	63
Discharge from hospital	NL	40 (4)	19
	DE	6 (1)	5
Transport	NL	0 (0)	0
	DE	33 (6)	16
Admission to hospital	NL	20 (2)	13
	DE	0 (0)	0

*N is 10 (NL) and 18 (GER)

In addition to the MRSA-net categories, new categories emerged based on the labels that did not fit (directly) into an existing MRSA-net category for HCWs (see Table V). *Other* surfaces as a very heterogeneous (65 Dutch, and 88 German unique cards) and often created category (72% of German and 100% of Dutch participants created a label like this). *Risks and contamination* and *Epidemiology and prevalence* are also used often (respectively 44% and 72% of German participants, and 70% of Dutch participants used labels that fit into these categories). The categories *Professions/disciplines*, *Patient information*, *Animals*, *Questions*, *Hospital* and *Household affairs* are among the rarely used categories, with a range of 0% to 30% of participants that created a similar label (see Table V).

Table V. HCW new categories based on label analysis

New categories	Language*	% that created this category (n)	Amount of (unique) cards placed in this category
Other	NL	100 (10)	65
	DE	72 (13)	88
Risks and contamination	NL	70 (7)	26
	DE	44 (8)	53
Epidemiology and prevalence	NL	70 (7)	21
	DE	72 (13)	32
Outside the hospital	NL	60 (6)	26
	DE	72 (13)	51
Isolation and protocols	NL	80 (8)	35
	DE	0 (0)	0
Other multi-resistant bacteria and co-morbidity	NL	40 (4)	1
	DE	28 (5)	14
Symptoms (disease)	NL	30 (3)	8
	DE	28 (5)	55
Legal issues	NL	0 (0)	0
	DE	61 (11)	23
Financial issues	NL	60 (6)	3
	DE	0 (0)	0
Consequences for the patient	NL	40 (4)	35
	DE	0 (0)	0
MRSA in the hospital	NL	20 (2)	9
	DE	17 (3)	20
Patient information	NL	0 (0)	0
	DE	17 (3)	13
Questions	NL	20 (2)	51
	DE	0 (0)	0
Special issues	NL	0 (0)	0
	DE	11 (2)	15
Household affairs	NL	0 (0)	0
	DE	6 (1)	3

*N is 10 (NL) and 18 (GER)

Public labels

The public's sorts and labels also overlap with MRSA-net categories. Table VI shows that *General information* and *Treatment* were created by the majority of participants of both countries (70-100%). In addition, *Contracting MRSA* was created by 80% of German participants and half of the Dutch participants reproduced the categories *MRSA and my profession* and *Contact in case of questions*. Many of the MRSA-net categories were reproduced by a minority of participants; *Contact with others* did not surface as a label in any of the participants' sorts, and *Hygiene and cleaning*, *Testing*, *The Netherlands/Germany and other countries*, *In the hospital*, and *Animals and pig farming* were only used by 10% of the participants.

Table VI. Public MRSA-net resembling group labels

MRSA-net categories	Language*	% that created this category (n)	Amount of (unique) cards placed in this category
General information	NL	100 (10)	59
	DE	70 (7)	45
Treatment	NL	70 (7)	56
	DE	90 (9)	43
Contracting MRSA	NL	40 (4)	30
	DE	80 (8)	63
Pregnancy and baby	NL	20 (2)	5
	DE	40 (4)	8
Contact in case of questions	NL	0 (0)	0
	DE	50 (5)	54
MRSA and my profession	NL	50 (5)	11
	DE	0 (0)	0
In the hospital	NL	30 (3)	9
	DE	10 (1)	4
Hygiene and cleaning	NL	10 (1)	11
	DE	10 (1)	10
Testing	NL	10 (1)	3
	DE	10 (1)	5
The Netherlands/ Germany and other countries	NL	10 (1)	24
	DE	10 (1)	2
Animals and pig farming	NL	10 (1)	10
	DE	0 (0)	0
Contact with others	NL	0 (0)	0
	DE	0 (0)	0

*N is 10 (NL) and 10 (GER)

The participants representing the public also use labels that do not correspond to existing MRSA-net categories, resulting in new categories (see Table VII). Most used categories (based on the participant-created labels) by Dutch participants include *Outside the hospital* (created by 60%), *Consequences for the patient* (created by 50%), and *Contact* (created by 50%). German most-used categories are *Prevention and protection* (created by 100%), *Disease and symptoms* (created by 80%), *Risk factors* (created by 80%), *Sources of infection and reservoirs* (created by 70%), *Consequences for the patient* (created by 60%), and *Other* (created by 60%).

Table VII. Public new categories based on label analysis

New categories	Language*	% that created this category (n)	Amount of (unique) cards placed in this category
Prevention and protection	NL	40 (4)	40
	DE	100 (10)	40
Disease and symptoms	NL	40 (4)	28
	DE	80 (8)	37
Risk factors	NL	30 (3)	27
	DE	80 (8)	34
Consequences for the patient	NL	50 (5)	49
	DE	60 (6)	52
Other	NL	30 (3)	28
	DE	60 (6)	59
Outside the hospital	NL	60 (6)	53
	DE	20 (2)	26
MRSA and other diseases	NL	40 (4)	26
	DE	10 (1)	1
Sources of infection and reservoirs	NL	0 (0)	0
	DE	70 (7)	28
Contact	NL	50 (5)	8
	DE	0 (0)	0
Financial issues	NL	0 (0)	0
	DE	40 (4)	6
Information for HCWs	NL	0 (0)	0
	DE	20 (2)	14

*N is 10 (NL) and 10 (GER)

Discussion

This card sort study shows that overall, the card sort approach to create an information structure for MRSA-net was successful. One year after its introduction, most of the main categories still correspond to the mental models of the target group, resulting from the label analysis. However, this study also demonstrated that additional categories surfaced from the information needs as sorted by the target groups. The cluster analysis showed categories/topics that are currently not addressed as a major or subcategory on the website, such as financial issues that surfaced among the Dutch public participants. In some cases, information corresponding to these themes (such as financial issues) is already present on the website, just not categorized as such. In addition, some cluster analysis results point towards information needs that are currently not or insufficiently being met by the website, such as the theme 'other pathogens'. Using "real" search queries as an input, provided us with the insights into additionally needed information and corresponding information architecture.

As with many technology aspects, information architecture should be subject to ongoing evaluation. In the case of a website with an internal search engine, search queries

can be a good indicator of shifts in information need, and, possibly, changes in the target group's mental models as well. For example, at the time of the development of MRSA-net, medical protocols were used as the main information source for the website regarding MRSA. These protocols typically focus most on clinical, and little on personal and societal relevance. User research during MRSA-net development [11], and the results of the current study show that the target groups (HCWs and the general public) need a non-expert driven approach. Even after applying a HCD approach during development, new categories emerge from the card sort, indicating new or changed information needs.

Reflection on card sorting

3 In this study, we combined a quantitative analysis of item clusters with a more qualitative category label analysis. Some approaches focus on the analysis of data based on category label analysis by incorporating all data into one spreadsheet and analyze the data based on a summary and interpretation of the categories [13]. This can lead to overall adequate conclusions: participant categories are summarized and generalized. Thus, if participant 'A' creates a category labeled *MRSA in general*, and participant 'B' labels a group *General Information*, these two categories are treated as equal. However, information on how many cards and how many unique cards are placed in this general category gives some insight into its strength, but overlooks the interrelatedness between items, because they are driven by label-interpretation and not the precise overlap of two seemingly (based on label) identical groups. In contrast, a focus on the item correlations and cluster analysis is facilitated by card sort programs such as UXsort, or EZsort [15, 5]. This approach offers insight into what information excerpts are related or linked to each other, in the participant's view.

In this study we found that the combination of the quantitative and qualitative analysis brings two advantages. It generates suggestions for information structure (how to group or structure certain content) and provides insight into the mental models that are associated with the information. Applying this combination is important, because the group labels may depict a mental model (and can be generalized among participants), but they do not always accurately represent the same content: participants placed quite different cards in certain generalized groups. For example, the standardized label *Consequences for the patient* entailed both cards referring to physical consequences of MRSA and MRSA-treatment (symptoms, side effects), as well as consequences regarding patient behavior (special precautions, preventive measures). Thus, patients may view MRSA as something that has both physical and behavioral consequences. Whether these consequences are the result of the disease or of the treatment, may not be relevant for every patient. So, besides clear input for design, card sorting informed us about participants' understanding and expectations regarding the information domain.

In this study, cluster analysis rendered quite clear clusters with satisfying overall agreement. However, when data is likely to be interpreted in different ways, and various overlapping categories (factors) are applicable to the data, performing factor analysis can be an insightful approach [16]. It allows items to be placed in multiple (overlapping) categories, thereby identifying more categories and relationships. However, visualizing the clusters in a similarity matrix, as we did in this study (see Figure 3), also enables researchers to identify overlap between categories when items from one category are also (but less than in their own category) placed with items from another category. This information can for example be used to create links between pages, to facilitate navigation.

With regard to the outcomes, we see striking resemblances as well as differences between the four groups. Both analysis methods demonstrate that HCWs (professionals) generate more homogeneous results than the general public in terms of agreement in clusters and groups created based on labels. This illustrates that the public's knowledge of the subject probably varies more and is influenced less by (professional) education. Some differences between the nationalities become apparent; German HCWs focus more on legal issues, whereas Dutch HCWs distinguish financial matters as a relevant subject within the MRSA theme, as well as protocols. Some of the differences can be explained by differences in the healthcare situation in both countries; *Transport* surfaced as a relevant category among German participants, which can be explained by the fact that German patients may be more likely to be transported from one location to another than Dutch patients, as care tends to be more centralized in bigger hospitals in the Netherlands whereas more smaller clinics exist in Germany. The differences show that tailoring based on specific target group is needed. However, all participants show a need for certain standard topics, most of which are already present on MRSA-net. For example, information labeled to address treatment and diagnostics is a uniform need, and a category that indicates how MRSA affects patients also surfaced from cluster analysis. Thus, the analysis of actual information search queries on MRSA-net confirmed most of the present categories and provides suggestions for additional themes to address on the website.

Relevance for research and practice

This study showed that card sorting can be a good starting point for meeting information needs: card sorting as applied in this study helped to structure and prioritize instructions and information. By using actual website use data, we identified information needs and (new) topics of interest within a certain domain that are not yet covered. Basic (background) information needs that give information and explanations on the domain (in this case MRSA) do not change (much), but due to changes in context, regulations and possibly media-coverage, new topics can emerge. Therefore, in formative research, the cards used for a card sort should not or only partially be based on current information

sources such as protocols. Rather, they should consist of, or be complemented with, practice-driven information needs such as (Google) search queries or scenario-based test results. This way, the card sort method can be applied as a formative and evaluative method.

Likewise, a card sort analysis as performed in this study may prove useful in analyzing social media outings and or search trends in search engines, using these outings or search queries as input for the cards. However, to ensure an optimal implementation of information technology in patient or HCW daily life or daily practice, a well-fitted information architecture does not suffice. HCD also asks for a critical eye on the target group's use context. In this particular case, we learned that information architecture is important and should be established, mostly to get an insight into the scope of users' information needs. Actual information searches may depend less on the information architecture, as far most of the website target content's views result from external search engine queries (Google) [17]. Therefore, conducting card sorts and establishing an information infrastructure (and evaluating its applicability over time) is important to get insight into information needs, but for actual website use, its applicability may be limited when (good) search engines index the website's content. Possibly, a difference exists between concrete (procedural) information needs (e.g., searches for one clear instruction or description) as opposed to more general, explorative information (declarative) needs in which users just want to scroll through the content to form an image of the topic [18]. Because MRSA-net was intended mainly as a quick question-answer website, good search engine indexing is pivotal as many quick answer-seeking quests start with Google. For keeping the spectrum of information up to (user-need) date, card sorting has proven to add valuable insights.

Limitations

Some differences in the German and Dutch card samples regarding content were present. On the one hand, this can be a result of the (random) samples that were drawn: the database of search queries was rather large so coincidental differences can always be present, even if we assume the search queries made in Dutch are overall the same as in German. However, as there are some differences between the Dutch and German MRSA control strategy and prevalence, these differences may have manifested in the information needs (and thus, search queries on MRSA-net) of the target group, accounting for the differences in card sample content. Aside from this, the sample drawn from the search queries database is with 100 items quite large; a 100 cards to sort seems to be about the maximum that is feasible to ask from participants [19]. This may be especially true for participants representing the general public, for whom the topic may be difficult to comprehend and thus categorize. Besides, given the amount of overlap that was found

when drawing the sample (and thus, replacing overlapping items with new randomly drawn items), suggests that at least the most important issues were included in the sample.

Another issue related to the 100-item card sample that was sorted, is the fact that some of the items appeared to be somewhat of an outlier, content-wise. Given the amount of cards placed in one group, participants apparently were reluctant to create groups of one card and they were not explicitly encouraged to do so if they felt a card (by itself, due to a lack of related cards in the sample) represented an important category. Rather, they created other or rest categories. In future studies, more emphasis could be placed on the interpretation of cards as a representation of a subdivision of information relevant on the domain, resulting in an overview and understanding of that domain instead of the task of creating groups for content of a website. This would make card sort results better usable for a broad application.

With regard to the generalizability of the resulting mental models to actual information needs and architecture, some remarks are in place. We were able to separately include HCWs and members of the general public (non-HCWs) in our study. However, the open search field search queries as applied to the public or HCW divisions of MRSA-net may not necessarily represent information needs of the general public or HCWs, respectively. As this website's use is anonymous, HCWs may have sought for information in the MRSA-net public section, and vice versa. This becomes clear in the sorting results where the general public identified groups that contain information for professionals and the HCWs identified groups that contain information for the general public. So, even though the sorts likely represent the mental models of the user group the *participant* represents, conclusions regarding information needs of website *users* should be drawn cautiously. In this line, providing an overview by tailoring information and information structure to a user group works optimally when one can be sure of who the actual user group is. In the case of MRSA-net, this may not always be the case. As a designer or researcher, establishing whose needs are most relevant to cater to in these types of target group-actual user mismatches, is crucial. In general, however, given the high visitor levels (around 11.000 per month for all user groups jointly), the website does seem to fulfill some information need [17]. This website was mainly (>90% of content views) accessed after a Google search; in these cases users directly landed on content pages. This implies that card sort to derive a website structure is a less urgent matter than understanding the target groups mental models and information needs. However, in our approach we were able to validate the information structure, and gain insight into our users' needs.

Conclusion

In this study we provide evidence that the card sort method renders long-term valuable results for (protocol) website information architecture. Moreover, the value of this method stretches beyond the design phase: it provides insight into users mental models and

changes in user information needs, when applied repeatedly. By using ecological data representing information needs as resulting from actual website use, card sorting can be used as an evaluative method as well, besides its appliance in formative development phases. This approach enables information managers to continuously adjust medical information to the target group, taking into account their (slightly) changing needs.

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Chapter 4. Guideline Implementation in Practice: Literature

This chapter is based on:

Wentzel, J., de Jong, N., Karreman, J., & van Gemert-Pijnen, L. 2012. *Implementation of MRSA Infection Prevention and Control Measures – What Works in Practice?* In *Infection Control – Updates*, 2012, C. Sudhakar (ed.), InTech.

Introduction

There have been increasing numbers of media reports about careless behaviour by healthcare workers, mainly involving insufficient cleaning practices and the absence of hand hygiene measures [1]. Although adherence to infection prevention and control measures has received a lot of attention in the media and in scientific literature, surprisingly little attention has been given to the implementation of the infection prevention and control strategies in healthcare practices. In the medical literature the focus is on the availability of national or regional MRSA surveillance data and guidelines for prevention and control. To date, hardly any data has been made available about the kinds of interventions that have been successful in implementing infection prevention and control.

Research has shown that an intensive infection prevention program could prevent about one-quarter to one-third of all hospital infections [2]. An example of such a successful policy is the 'search-and-destroy' strategy that has been introduced in the Netherlands, to prevent the spread and outbreak of infections caused by multi-resistant bacteria such as Methicillin-resistant *Staphylococcus Aureus* (MRSA). However, adherence to this policy still remains a problem. It is known from prior research [3, 4] that healthcare workers are insufficiently aware of infection control measures; they do not understand the rationale behind these measures and think that infection control is not their problem, that it is mainly an issue for hygiene experts.

Research in the social sciences has shown that improving safety in hospitals requires a tailored strategy to persuade people to change their attitudes and behaviours [5]. Furthermore, changing routines and habits in healthcare is not easy: it requires an integral approach, with activities addressing human behaviour, culture, incentives and other managerial reinforcement activities, and of course adequate information about safety regulations [3, 4, 6]. A multifaceted implementation strategy might be a solution [6,7]. Such a strategy should include interventions aimed at different levels: the management of healthcare institutions, the behaviour of healthcare workers and the quality of the infection control guidelines. However, what empirical evidence exists for a multi-faceted implementation strategy? And how successful are these strategies? To investigate this, we conducted a systematic literature review. This review will be used to develop an implementation strategy that fits the habits and culture of hospital-based healthcare workers (HCWs) in hospital care settings. In this review, we searched for empirical studies to investigate and identify effective implementation strategies for improving adherence to MRSA prevention and control measures. The following questions guided our review of the literature:

- What implementation strategies are used?
 - What is the foundation of these strategies (theories, experience, etc.)?

- What research designs were used to measure the effects of the implementation strategies?
- What effects are reported?
 - On adherence to the measures?
 - On the reduction of costs?
 - On the reduction of MRSA?

Method

The York protocol for systematic reviews [8] was used to guide the review process. Literature searches were carried out in the online databases Scopus, ISI Web of Knowledge and the Cochrane Library. In addition, we hand-searched the indexes of the *Journal of Hospital Infection* (JHI), the *American Journal of Infection Control* (AJIC) and *Clinical Microbiology and Infection* (CMI) for relevant publications. We searched for studies describing the implementation of MRSA prevention or control measures. The publications were included in the review if they met the inclusion criteria listed in Table 1. Most important was that the publications described an implementation strategy and implementation outcomes. Two independent reviewers (NdJ, JW) applied the inclusion criteria to the publications in a title screening round, followed by an abstract and a full-text screening round. After each round, the reviewers compared their judgments and resolved discrepancies through discussion. The included studies are summarized in a data table, and the study features and results are summarized and compared. Due to the heterogeneity of the data and the limited number of included studies, no meta-analysis was performed.

Table 1. Inclusion Criteria

<i>Publication Type</i>
(Scientific) Journal article, published between 2005-2010
<i>Scope of Studies</i>
Implementation of an evidence-based MRSA prevention or control measure. The implementation strategy must be described.
<i>Study Settings</i>
Primary-/secondary-care facilities, long-term care facilities, nursing homes
<i>Outcome measure</i>
Implementation outcomes (mostly behavioural) must be given:
<ul style="list-style-type: none"> • Behavioural (e.g. adherence to implemented measure, knowledge) • Clinical (e.g. prevalence rates, infection rates, deaths) • Organizational (e.g. changes in Length of Stay (LoS), expenditures, costs)

Results

Article screening

The search strategy resulted in 661 potentially relevant publications (after duplicates were removed). The screening process and outcomes are shown in Figure 1; 29 publications were included in the review. The characteristics of these publications are summarized in Table 2. The characteristics and outcomes of the included studies are discussed in the following sections. The numbers we cite correspond to the publications summarized in Table 2 (placed at the end of this chapter).

Study design

Among the included studies, there was one randomized controlled trial (RCT) [9]. In eight studies, a time series design was used [10, 17, 22, 23, 25, 30, 31, 33], and in fourteen studies a before and after design was used [11-13, 15, 18-20, 26, 27, 29, 34-37]. Five studies applied a combination of time series and before and after design [14, 16, 21, 24, 28].

Figure. 1. Results of the screening process

A: Insufficient implementation strategy information; B: No compliance rates, no implementation results described; C: Article is a viewpoint/review; D: Article was not written in English; E: Article is a report of conference proceedings; F: Other.

MRSA prevention and control measures

Different measures were implemented to prevent or control MRSA. In some studies a single MRSA prevention or control measure was implemented, in others a bundle of measures was implemented. *Hand hygiene* was implemented as a stand-alone measure in seven studies [12, 13, 15, 18, 21, 28, 37] and as part of a bundle of measures in eleven studies [9, 11, 14, 16, 19, 22, 24, 25, 27, 29, 32]. *Environmental hygiene* was implemented as a standalone measure in one study [20] and as part of a bundle of measures in two studies [9, 25]. The use of *personal protective equipment* such as gloves or gowns was implemented as part of a bundle of measures in four studies [9, 11, 24, 29]; it was implemented as a stand-

alone measure in none of the studies. *Medication*, or the correct use of antibiotics, was implemented as a stand-alone measure in six studies [10, 17, 23, 30, 31, 33]; in none of the included studies was it part of a bundle of measures. In two studies [34, 35], *patient screening* was implemented as a stand-alone measure, and in six studies [11, 16, 19, 24, 25, 27] it formed part of a bundle of measures that was implemented. *HCW screening* was implemented only as part of a bundle of measures, in one study [25]. *Patient isolation* was implemented as stand-alone measure in one study [36], and was part of a bundle of measures in five studies [11, 14, 24, 26, 27].

Implementation strategies and their foundation

Various strategies were used to implement the MRSA prevention and control measures. Most implementation strategies are set up because of the empirical observation of non-adherence to clinical guidelines, thus creating an impediment to successful MRSA control. The theoretical foundation of the chosen strategies is often unclear, or not specified.

Most studies, 24 out of 29, combined different elements [9-25, 27, 28, 30, 32-45]. In five studies the implementation strategy consisted of one component [26, 29, 31, 36, 37]. The strategies used are summarized below:

- *Audit and feedback* was performed and given by trained nurses or auditors, infection control specialists, or multidisciplinary teams (nineteen studies [9, 10, 12-14, 16, 17, 19-25, 27, 28, 30, 32, 35]).
- *Reminders* were used in eighteen studies [11-17, 19, 24-28, 31, 34-37], for example pop-ups, fluorescent tape drawing attention to hand-cleaning facilities, posters or messages clipped to patient charts.
- *Educational meetings* were held, for example to inform HCWs about the measure or to demonstrate new working methods or hygienic practices (seventeen studies [9, 11-14, 16, 20-24, 27, 29, 30, 34, 35]).
- *Mass media* were used in fourteen studies [11, 13-16, 18, 19, 21, 25, 27, 28, 32, 36, 37]; posters, and to a lesser extent brochures or flyers, were used to remind or instruct HCWs about the implemented measures. Role models (hospital management or leaders) were sometimes depicted, or HCWs were involved in the creation of the poster [19, 25, 37].
- *Technology* was used in ten studies [9, 11, 13, 21, 25, 26, 29, 31, 34, 35] in the context of education (PowerPoint presentations, training via DVD), electronic order forms, popups assisting medication choice or screening of patients.
- *Changes in physical structure, facilities and equipment* were applied in eight studies [12-14, 16, 19, 20, 24, 35]. These changes included strategically placed hand disinfectant dispensers, equipping HCWs with pocket bottles of hand disinfectant, or new cleaning materials (cloths), the bundling of protective gear and the availability of a test kit for screening.

- *Educational materials* were distributed in eight studies [12, 13, 16, 18, 21, 25, 28, 35]. Brochures, newsletters or instructional pocket cards were given to HCWs, often focused on applying correct (hand) hygiene.
- *Local opinion leaders* guided the implementation process in six studies [9, 12, 13, 23, 32, 35], sometimes by reinforcing good infection control, or acting as a link worker between the professions and management.
- *Clinical multidisciplinary teams* were used in five studies [10, 14, 28, 30, 33] to guide the implementation of a MRSA control measure. Via cooperation or consultation these teams supported the measures taken, for example by approving antibiotic prescriptions.
- *Educational outreach* was carried out in five studies [14, 18, 23, 33, 35] to teach HCWs onsite and sometimes on demand how to apply the implemented measure.
- *Rewards* for correctly performing the implemented measures were given in two studies [12, 24], either to individuals directly after observing correct behaviour, or to groups based on periodic adherence results.
- *A patient-mediated intervention* was implemented in one study [18]; patients and visitors were actively addressed to perform the desired hand hygiene behaviour and motivate adherence among staff.
- *AB permission/formulary* was applied in one study [10] where permission to use a certain antibiotic was required.

Outcomes

We classified the reported effects into three categories: *adherence* to the measures, reduction of *costs* and *reduction of MRSA*.

In twelve studies [9-11, 15, 17, 20, 21, 25, 26, 32, 36] significant improvements (e.g., fewer prescriptions for antibiotics, more correctly executed hand hygiene, reduced expenditure on materials) in *adherence* to the MRSA control measures were observed. Similar positive results were observed in fourteen studies [12-14, 16, 18, 22-24, 28, 30, 31, 33, 35, 37], although these results were not statistically tested. In one of the studies [24], negative effects were observed: adherence to the measures increased in the first year but decreased thereafter.

Acquiring a hospital-associated infection (HAI) results in a longer length of stay for the patient and poses many additional *costs*. Therefore, reductions in length of stay are an important outcome associated with decreased MRSA infection rates. Cost savings, or at least cost-neutral intervention effects, were observed in four studies [13, 18, 23, 35]. On the other hand, increased isolation and increased expenditure also posed costs, as described in one study [26]. However, in this study, these increased costs were not compared to possible savings due to prevented infections. In another study [27], improved screening led to increased lengths of stay (pre-ICU and ICU), because MRSA detection increased.

In nine studies [16, 20-22, 24, 25, 29, 33, 34], significant clinical improvements were reported, including MRSA prevalence, MRSA infection rates and susceptibility rates. Positive effects were also observed in eleven other studies [10, 13, 15, 18, 19, 23, 28, 30-32, 35], although these results were not statistically tested.

Conclusion and discussion

The results of our review show that in most cases hygiene experts or an infection control team (nurse, infectious disease specialist, microbiologist) are the developers of implementation strategies. These strategies are driven by empirical observations and audits. The theoretical foundation of the chosen strategies is often unclear. No references to theories and models of human behavior are made. However, some articles indicated that a literature search was carried out.

When looking at the implementation strategies, we can conclude that in most cases a multifaceted strategy was carried out. This strategy entails a combination of several activities:

- Education or training modules for HCWs, sometimes mandatory, taking various forms (DVDs, PowerPoint presentations, posters, meetings, brochures) to improve hand hygiene and compliance with protocols.
- Inspections of the adherence to the safety program and of hand washing behaviour via audits, on-site instructions, and observations by hygiene experts or trained auditors. Results were communicated to management and demonstrated via feedback meetings.
- Environmental interventions (red lines at the entrance to high-risk wards, talking walls) to remind HCWs to behave safely in that particular area and to provide antibiotic policy support via guidelines and pocket cards.

The implementation pathway consists of *education-inspection-feedback* rounds; unfortunately it is unclear who is responsible for the management of the intervention strategies and who invests in these activities. No business model seems to underpin the entire implementation strategy.

To answer the research question about the effect of the implementation strategies, we reviewed the research designs that were used to measure their effects. In general, quasi-experimental designs (before and after and time series designs) underpin the research activities. Implementation outcomes are usually measured in a before-and-after design, where they do not concern antibiotic use, and therefore provide little insight into temporal changes in implementation results or adherence. HCWs are the main target group in the research designs. It is unclear who these designs seek to manage (researchers, HCWs, management) in their execution or whether a project manager is responsible for this. Trained nurses or infection control teams are sometimes used. In most cases

quantitative instruments are used to measure the effects on knowledge and behaviour (questionnaires, self-reporting of behaviour, material use, and hand hygiene) and on a reduction in MRSA and antibiotic doses (lab statistics). The effects on cost/benefits were sometimes measured, addressing utilizations such as reduced length of stay. In general the outcomes are promising. However, the extent to which the outcomes are related to the implementation strategies is not clear, except for the routine screenings and reduced MRSA rates. The outcomes on cost-savings are especially hard to analyze. It remains unclear what is measured, how it is measured and to what purpose. Long-term effects are almost never addressed.

Due to several shortcomings in research designs, the overall impact of the implementation strategies could not be measured sufficiently. Shortcomings in the research designs include, for example, the one-sided focus on HCWs. We know from prior research [4] and from behaviour change models that not only is a multifaceted strategy needed to change safety behaviour, but that a multi-perspective stakeholder view (HCWs, infection experts, patients, the safety policy of the management of the organization) is necessary to obtain insight into the cost/benefits of the implementation strategy and to discuss the long-term implications of the strategy for the organization and workflow [38]. This requires a theory or innovation-driven approach that grounds the implementation strategy. Such an approach enables an assessment of which activities are successful for whom (patient, HCWs, management) and what the interaction effects of the different components of the strategy are.

Another shortcoming concerns the chosen study designs. Authors of the included studies refer to the difficulties in matching control and intervention groups, the high rates of dropouts and the low volume of included respondents, and confounding factors that cannot be excluded. These shortcomings are well-known impediments related to RCTs and the self-reported behaviours. In fact, these shortcomings cannot be avoided due to the study of real-time behaviours and contextual factors that influence these behaviours. Therefore, these factors should not be regarded as nuisances, as the authors of many RCT publications do; they are in fact the key issues that are important in implementation studies aimed at changing culture and behaviour. For example, some authors reported problems in implementing the activities due to a lack of resources (a result of the economic downturn) to manage the implementation and problems with measuring the effects of each component of the implementation strategy due to financial constraints. A lack of transparent funding models and lack of management support made the participation of different institutes or wards in the research projects problematic, resulting in only small pilot projects being carried out. These financial barriers should not be reported as shortcomings; rather, these factors should be determined by the key stakeholders and considered as critical factors for changing behaviour and the culture of safety in hospitals or other institutions.

In addition, some authors reported a lack of commitment on the part of nursing personnel to participate in the implementation projects. It appeared that some personnel were uncertain about the implications of several measures. For example, they were concerned that patients would not feel as clean after being washed with wipes instead of soap and water. The level of commitment of HCWs and management is one of the main conditions for success in programs for innovation or change. The impediments indicate that the implementation strategies are expert-driven rather than stakeholder-centered. Changing safety behaviour in hospitals is first and foremost a cultural problem of management and staff, which requires that implementation strategies should address that level.

How to improve the implementation strategies? Given the fact that the implementation strategies influenced the attitude and knowledge of HCWs in a positive way, intentions to behave safely increased, and that MRSA rates decreased in several studies, the question is how to boost the impact of the implementation strategies. *Education-inspection-feedback* rounds could be one way to do this. Based on prior experience in infection management control and on information gathered from other studies of innovation management [39, 40], we argue that the participation of staff and management is crucial to the development and implementation of interventions, to increase applicability, accountability and ownership and to create a fit between the proposed activities and the culture of the organization [41]. In addition, both positive and negative incentives are needed to encourage staff to do the right things at the right times. Change agents and demonstration of best practices will improve the incorporation of safety behaviour. To enhance the transparency of the implementation program and strategies, communication of results or key factors for success should be available to staff. Communication should include insights into results related to infection management (prevalence and incidence rates of MRSA, identification of increasing/decreasing trends), the business model underpinning the program (resources, investments, additional costs) and benchmarking (how are we doing and what are others doing?). It is also important to demonstrate to the management and staff that the investment costs of the intervention can be less than the costs of not adopting an MRSA-infection control program.

Another point of attention is the use of media to implement the strategies. Even though evidence of the usefulness and effectiveness of computerized decision support or reminders exists [42], it is not often used. We found that in ten studies DVDs, PowerPoint presentations, educational programs available online or on CD-ROM, and electronic alerts or reminders were used. This is rather remarkable in our Internet-driven world. Web-based communications systems in particular can increase staff knowledge and provide access to accurate, adequate and easy to understand information [43]. In prior and on-going research projects aimed at cross-border infection control (MRSA-net; EurSafety Health-net) we developed stakeholder-driven, web-based communication systems, based on

national infection control standards, to support staff and patient behaviours (see for example [4]). This resulted in fewer errors, time savings and also appropriate behaviour by HCWs.

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Table II. Characteristics of the studies included in the systematic review

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
[9] Baldwin, et al., 2010, Ireland	Educational meetings	<p>Behavioural</p> <p><i>In-person observations</i></p> <p>Mean audit score was higher in the intervention than in the control homes at 3 months, 6 months and 12 months.</p> <p>Clinical</p> <p>MRSA positive screenings were similar in intervention and control homes at 3 months, 6 months and 12 months.</p> <p>MRSA prevalence rates among staff were similar in intervention and control group at 3 months, 6 months and 12 months.</p>
	Local opinion leaders	
	Audit and feedback	
	Technology supported	
	Implementation foundation	
	Theoretical: absence of IC research in nursing home setting	
	Infection control measure	
	Hand hygiene	
	Design	
	Environmental hygiene	
	Personal protective equipment	
	RCT	
[10] Bassetti, et al., 2009, Italy	Audit and feedback	<p>Behavioural</p> <p>Significant reduction in cephalosporin use.</p> <p>Significant increase in use of ciprofloxacin.</p> <p>Clinical</p> <p>Significant reduction in MRSA due to intervention.</p> <p>An increase in susceptibility to piperacillin/tazobactam observed during the pre-intervention period in <i>P. aeruginosa</i> isolates ceased after the change in antibiotic policy.</p> <p>Increase in susceptibility to ciprofloxacin in <i>K. pneumoniae</i> isolates after the intervention began, although an abrupt change in the percentage of susceptible isolates followed termination of the intervention.</p> <p>Decrease in susceptibility to piperacillin/tazobactam and imipenem in <i>K. pneumoniae</i> isolates and an increase in susceptibility to ciprofloxacin in <i>P. aeruginosa</i> isolates was observed during the entire surveillance period, with no significant changes due to intervention.</p>
	AB permission	
	Formulary restrictions	
	Clinical multidisciplinary teams	
	Infection control measure	
	Medication	
	Design	
	Time series design	
[11] Burkitt, et al., 2010, United States	Educational meetings	<p>Behavioural</p> <p><i>Questionnaires</i></p> <p>Significant increase in proportion of respondents who reported using alcohol-based hand rubs rather than soap and water to clean their hands.</p> <p>Significant increase in mean number of knowledge questions answered correctly.</p>
	Reminders	
	Mass media	
	Technology-supported	
	Implementation foundation	

	Theoretical: lack of measurement of actual changes in knowledge due to education	<p>Infection control measure</p> <p>Hand hygiene</p> <p>Personal protective equipment</p> <p>Patient screening</p> <p>Patient isolation</p> <p>Design</p> <p>Before and after design</p>	<p>Significant increase in proportion of respondents who agreed or strongly agreed that MRSA was a problem in their unit.</p> <p>Significant increase in proportion of respondents who reported being comfortable reminding other staff about proper hand hygiene and contact precautions.</p> <p>Significant decrease in job satisfaction. Significant increase in proportion of respondents who reported using prevention practices.</p> <p>Significant increase in proportion of respondents reporting at least one barrier to proper hand hygiene, primarily because they feared that hand rubs or soap damages the skin or because they forgot to perform hand hygiene.</p>
[12]Camins & Fraser, 2005, United States	Distribution of educational materials	<p>Behavioural</p> <p><i>Observations in person</i></p> <p>Hand hygiene compliance increased from 1st to 4th quarter of 2004. (Details on material use or observed compliance not given).</p>	
	Educational meetings		
	Local opinion leaders		
	Audit and feedback		
	Reminders	<p>Implementation foundation</p> <p>Theoretical: CDC Hand Hygiene Task Force recommendations</p> <p>Infection control measure</p> <p>Hand hygiene</p> <p>Design</p> <p>Before and after design</p>	
	Rewards		
[13]Carboneau, et al., 2010, United States	Distribution of educational materials	<p>Behavioural</p> <p><i>Observations in person</i></p> <p>Hand hygiene compliance increased from 17-months pre-intervention to 7 months post-intervention.</p> <p>Clinical</p> <p>Decrease in MRSA-positive cases from 17 months pre-intervention to 7 months post-intervention and decrease in invasive MRSA cases.</p> <p>Financial</p> <p>Net dollar savings due to MRSA infection prevention of US \$276,500 over study period (August 1, 2006 to September 30, 2007)</p> <p>41 MRSA infections were prevented during study period, thereby decreasing length of stay, resulting in a savings of \$354,276, a net hard-dollar savings of \$276,500.</p> <p>Increased hand sanitizer costs of \$40,000 per year.</p>	
	Educational meetings		
	Local opinion leaders		
	Audit and feedback		
	Reminders		
	Mass media		
	Changes in physical structure, facilities and equipment		
	Technology-supported		
	Implementation foundation		
	Theoretical: prior research solutions, including scientific articles and at other hospital		
	Infection control measure		
	Hand hygiene		

[14]Cheng et al., 2009, China	Design Before and after design	Behavioural <i>Observations in person</i>
	Educational meetings	Increased hand hygiene adherence.
	Educational outreach Audit and feedback (trained auditors) Reminders Mass media Clinical multidisciplinary teams Changes in physical structure, facilities and equipment Infection control measure Hand hygiene Patient isolation Design Before and after design Time series design	Increased use of alcohol-based hand rub. Clinical Decreased MRSA infection rates Change in ICU onset MRSA infections between phase 1 and 2 (ICU renovation) and between phase 2 and 3 (hand hygiene campaign).
[15]Davis, 2010, United Kingdom	Behavioural <i>Video observations</i>	Significant increase in hand hygiene compliance of HCWs but no significant increase for patients.
	Duration 6 months	Clinical <i>Lab statistics</i>
	Hand hygiene Design Before and after design	Decrease in MRSA incidence (from 2 to 0 cases during 6-month periods), reference unit: increase in MRSA incidence (from 0 to 2 cases during 6-month periods).
[16]Eveillard, et al., 2006, France	Behavioural	Increase in use of waterless alcohol-based hand disinfectants.
	Educational meetings Educational outreach Audit and feedback Reminders Mass media Changes in physical structure, facilities and equipment Implementation foundation Empirical: existing programme to limit the spread of MRSA was not effective Infection control measure Hand hygiene Patient screening Design	In 2004, the use of alcohol-based hand disinfectants was twice as high in high-risk wards than in low-risk wards. <i>Questionnaire</i> 46% of 450 employees declared they had attended at least one educational session. Number of patients screened on admission or after intra-hospital transfer increased Clinical Decrease in the incidence of newly acquired MRSA infections in high-risk wards. Decrease in the incidence of risk of acquisition. Decrease in proportion of acquired MRSA. Number of MRSA carriage on admission did not increase. Proportion of MRSA/total S. aureus within the first 48 hours decreased.

Before and after design Time series design	
[17]Fowler, et al., 2010, England	Behavioural Significant decrease in targeted ABs: Cephalosporins and Amoxicillin/clavulanate Significant increase in the long-term trend of benzyl penicillin. Significant increase in level of amoxicillin. Non-significant change in trend (not reversed long-term). Non-significant change in level and trend of trimethoprim.
	Clinical Significant decrease in CDI (clostridium difficile infection) and Incident Rate Ratio. Non-significant change in MRSA infections. Non-significant change in crude mortality.
	Financial No change in length of stay throughout study.
	Behavioural <i>Observations in person</i> Increase in overall staff hand hygiene compliance.
	Clinical Decrease in MRSA infections vs. positive screenings. Decrease in MRSA infections.
	Financial <i>Finances</i> Based on comparative year, 51 cases of infection were prevented in study year, resulting in net savings of CAN\$688,843.
[18]Gagné, et al., 2010, Canada	Behavioural Exact compliance rate unclear, but all staff/family entering was send back by 'door monitor' in case of non-compliance; compliance is assumed to be close to 100%
	Clinical MRSA acquisition rate decreased. Resistance increased, due to a clonal outbreak of rifampicin-resistant MRSA.
	Implementation foundation Empirical: own observation that MRSA kept spreading despite staff decontamination
	Infection control measure Hand hygiene
	Design Before and after design
	Behavioural Exact compliance rate unclear, but all staff/family entering was send back by 'door monitor' in case of non-compliance; compliance is assumed to be close to 100%
[19]Gillespie, et al., 2007 Australia	Clinical MRSA acquisition rate decreased. Resistance increased, due to a clonal outbreak of rifampicin-resistant MRSA.
	Implementation foundation Empirical: own observation that MRSA kept spreading despite staff decontamination
	Infection control measure Hand hygiene
	Design Before and after design
	Behavioural Exact compliance rate unclear, but all staff/family entering was send back by 'door monitor' in case of non-compliance; compliance is assumed to be close to 100%
	Clinical MRSA acquisition rate decreased. Resistance increased, due to a clonal outbreak of rifampicin-resistant MRSA.
[20]Goodman, et al., 2008, United States	Implementation foundation Empirical: own observation that MRSA kept spreading despite staff decontamination
	Infection control measure Hand hygiene
	Design Before and after design
[20]Goodman, et al., 2008, United States	Behavioural Exact compliance rate unclear, but all staff/family entering was send back by 'door monitor' in case of non-compliance; compliance is assumed to be close to 100%
	Clinical MRSA acquisition rate decreased. Resistance increased, due to a clonal outbreak of rifampicin-resistant MRSA.
	Design Before and after design

[21]Grayson, et al., 2008, Australia	Changes in physical structure, facilities and equipment Implementation foundation Other: development of a novel and nontoxic tracking marker that is visible only under UV lamp Infection control measure Environmental hygiene Design Before and after design	Mark removal was more frequent during the intervention period than during baseline period. Additional predictors of mark removal included type of ICU and type of surface. No difference in the effect of the intervention between surgical and medical ICUs. Clinical Type of ICU was predictive of positive surface-culture results, as was type of surface. Multivariate models showed significant intervention effect, with reduced environmental MRSA and VRE contamination when cultures were used as the unit of analysis and data were clustered by room. No direct association between the removal of the mark from a specific surface and the likelihood that the surface culture would yield MRSA or vancomycin-resistant enterococci (VRE). Multivariate models assessing the proportion of marks removed showed that there were 30% fewer positive cultures for every 10% increase in the proportion of removed marks.
	Distribution of educational materials Educational meetings Audit and feedback Mass media Technology-supported Implementation foundation Empirical: prior success of a single-site HHCCP Infection control measure Hand hygiene Design Before and after design, time series design	Behavioural <i>Observations in person</i> Within group pilot programme: significant increase in hand hygiene compliance. After an initial increase, some sites showed some transient declines in compliance (related to changes of project officers). Within group pilot programme: alcohol-based hand rubs (ABHRS) increased, but correlated poorly with hand hygiene compliance. <i>Observations in person</i> Within group state-wide: significant increase in hand hygiene compliance after 4 months and after 11-12 months. <i>Material use</i> Within group state-wide: ABHRS increased, but correlated only roughly with HH compliance rates. Clinical Pilot group: significant decrease of patients with MRSA bacteremia. Significant reduction of the total number of clinical MRSA cases. State-wide: decrease in patients with MRSA bacteremia. Significant decrease in the number of clinical MRSA isolates, but this trend had already started before HHCCP.
[22]Harrington, et al., 2007, Australia	Educational meetings Audit and feedback Duration 24 months	Behavioural <i>Observations in person</i> Overall rate of usage of the standard of all products increased. Clinical

[23]Holder & Zellinger, 2009, United States	<p>Infection control measure</p> <p>Hand hygiene</p> <p>Other (sign put up in case of MRSA)</p> <p>Design</p> <p>Time series design</p> <p>Educational meetings</p> <p>Educational outreach</p> <p>Local opinion leaders</p> <p>Audit and feedback</p> <p>Duration</p> <p>2 months</p> <p>Infection control measure</p> <p>Medication</p> <p>Design</p> <p>Time series design</p>	<p>New patients with MRSA in the ICU decreased.</p> <p>Hospital-wide rate of new patients with MRSA decreased.</p> <p>MRSA central line-associated bloodstream infection (CLABSI) rates in ICU decreased.</p> <p>Decrease in hospital-wide rate of episodes of MRSA bacteremia.</p>
	<p>Behavioural</p> <p><i>Patient documentation</i></p> <p>Compliance increased.</p> <p>Clinical</p> <p>Bloodstream infection (BSI) rates decreased after implementation of the chlorhexidine bath procedure.</p> <p>Rate of MRSA/VRE colonization decreased after implementation of the chlorhexidine bath procedure.</p> <p>Financial</p> <p>75% reduction in BSIs over 6 months and increased costs per bath led to a projected cost savings of \$1.56 million per year if chlorhexidine baths were used in all hospital ICUs.</p>	
[24]Huang, et al., 2006, United States	<p>Educational meetings</p> <p>Audit and feedback</p> <p>Reminders</p> <p>Rewards</p> <p>Changes in physical structure, facilities and equipment</p> <p>Duration</p> <p>Sterile CVC placement: 10 months. Alcohol-based hand rubs: 1 month. Hand hygiene campaign: 14 months. Routine surveillance: 12 months</p> <p>Infection control measure</p> <p>Hand hygiene</p> <p>Personal protective equipment</p> <p>Patient screening</p> <p>Patient isolation</p> <p>Design</p> <p>Before and after design, time series design</p>	<p>Behavioural</p> <p><i>Observations in person</i></p> <p>ABHR institution and hand hygiene campaign increased compliance in the first campaign year, but decreased thereafter.</p> <p><i>Lab statistics (PD)</i></p> <p>Routine MRSA surveillance caused increase in compliance after institution of daily physician orders for admission and weekly nares cultures. Clinical</p> <p>Campaign to promote sterile CVC precautions caused substantial decrease in all-cause catheter-associated bacteremia in ICUs.</p> <p>Among the interventions, only routine ICU MRSA surveillance was associated with a significant decrease in the incidence density of MRSA bacteremia.</p> <p>After 16 months, routine screening was associated with a decrease in hospital-associated incidence density in ICUs, in non-ICUs, and hospital-wide.</p> <p>Routine screening was associated with a decrease in hospital-associated incidence density in ICUs, in non-ICUs, and hospital-wide. All findings were statistically significant.</p> <p>Routine surveillance caused significant reduction in MRSA acquisition in ICUs when comparing the first and last halves of the intervention period, exclusive of the phase-in period. This was despite a stable MRSA importation rate into ICUs.</p> <p>No significant secular trend and no impact of any infection control interventions on rates of methicillin-susceptible <i>S. aureus</i> (MSSA) bacteremia.</p>

[25]Johnson, et al., 2005, Australia	<p>Distribution of educational materials</p> <p>Audit and feedback</p> <p>Reminders</p> <p>Mass media</p> <p>Technology-supported</p> <p>Implementation foundation</p> <p>Theoretical: scientific articles</p> <p>Duration</p> <p>36 months</p> <p>Infection control measure</p> <p>Hand hygiene</p> <p>Environmental hygiene</p> <p>Patient screening</p> <p>HCW screening</p> <p>Environmental screening</p> <p>Design</p> <p>Time series design</p>	<p>Behavioural</p> <p><i>Observations in person</i></p> <p>Overall hand hygiene compliance improved at 4 months, and was maintained at the same level at 12 months.</p> <p>In individual sentinel areas, compliance rates improved significantly between pre-intervention and 4 months post-intervention in all areas.</p> <p>Use of ABHRS products increased in all sentinel areas.</p> <p>Clinical</p> <p>MRSA colonization rates did not change in any of the sentinel areas during OCS. Rate of healthcare worker MRSA colonization did not decrease in sentinel areas except in the ICU. Environmental contamination did not change significantly during OCS.</p> <p>Significant decline in total clinical MRSA infections per 100 patient-discharges over 36 months.</p> <p>For patient episodes of MRSA bacteremia, the monthly rate during the 28-month pre-intervention period was static, but fell significantly in the post-intervention period. By the 36th month, the monthly rate of MRSA bacteremia had decreased.</p> <p>Total clinical isolates per month of ESBLs increased during the 28 months before intervention, but had fallen by more than 90% by the 36th month of OCS.</p>
[26]Kho, et al., 2008, United States	<p>Reminders</p> <p>Technology-supported</p> <p>Implementation foundation</p> <p>Theoretical: low compliance (delay) associated with manual/paper-based information systems; computerized reminders appear promising</p> <p>Duration</p> <p>12 months</p> <p>Infection control measure</p> <p>Patient isolation</p> <p>Design</p> <p>Before and after design</p>	<p>Behavioural</p> <p><i>Computer logs</i></p> <p>Significant increase in proportion of correct contact isolation order.</p> <p>Mean time between ward arrival and isolation order decreased</p> <p>Acceptance of the reminder increased.</p> <p><i>Questionnaire</i></p> <p>19/20 survey respondents reported that the reminder either had no negative effect on workflow or saved them time.</p> <p>25/27 agreed with automatic contact isolation, and half of these would simultaneously request surveillance swabs.</p> <p>Clinical</p> <p><i>Lab statistics</i></p> <p>During the intervention period, the number of patients with known MRSA or VRE increased which reflected an increased ability of the IC service to both identify patients and update the list. National trend of MRSA/VRE increased during the study (no significant difference between baseline and post-intervention)</p> <p>Financial</p> <p>Annual isolation gown expenditures increased 23% from the same time period a year earlier (from US\$167,000 to US\$205,000).</p>

No calculations of cost savings in prevented nosocomial infections made.	
[27]Kurup, et al., 2010, Singapore	Behavioural
	Between groups: compliance in performing all study-related swab activities appeared better in the SICU, but the difference between the ICUs was not statistically significant
	Clinical
	AST detected MRSA in at least 137 of the 653 patients (21.0%). In contrast, clinical cultures for MSRA were positive in only 12 patients (1.8%).
	No significant overall improvement in detection rate when including axilla and groin sites in the AST.
	No improvement in detection rate in patients admitted to MICU, slight improvement in SICU.
	Inclusion of axilla and groin sites did not affect the MRSA detection rate during the ICU stay and at discharge, both overall and when the ICUs were analysed individually.
	Between groups: the rate of MRSA colonization detected by AST during the ICU stay or at ICU discharge was higher in SICU than MICU.
	No significant difference in MRSA infection rate pre- and post-intervention in both ICUs combined or when analysed individually.
	Less variability in MRSA rates post-intervention; the 95% CI at post-intervention was narrower than that at pre-intervention.
[28]Lederer, et al., 2009, United States	Septic shock at ICU admission was more common in MRSA-colonized patients than in non-colonized patients.
	Financial
	Detection of MRSA at any point was associated with longer pre-ICU length of stay, longer duration of antibiotic therapy, and longer ICU length of stay.
	Behavioural
	Increased hand hygiene compliance with sustained rates greater than 90%.
	Clinical
	MRSA healthcare-associated rate decreased, representing a 54% reduction associated with improved compliance.
	Implementation foundation
	Theoretical and empirical: CDC recommendations and observed low compliance
	Duration
[27]Kurup, et al., 2010, Singapore	12 months
	Infection control measure
	Hand hygiene
	Patient screening
	Patient isolation
	Design
	Before and after design
	Behavioural
	Between groups: compliance in performing all study-related swab activities appeared better in the SICU, but the difference between the ICUs was not statistically significant
	Clinical
[28]Lederer, et al., 2009, United States	AST detected MRSA in at least 137 of the 653 patients (21.0%). In contrast, clinical cultures for MSRA were positive in only 12 patients (1.8%).
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	Less variability in MRSA rates post-intervention; the 95% CI at post-intervention was narrower than that at pre-intervention.
	Septic shock at ICU admission was more common in MRSA-colonized patients than in non-colonized patients.
	Financial
	Detection of MRSA at any point was associated with longer pre-ICU length of stay, longer duration of antibiotic therapy, and longer ICU length of stay.
[28]Lederer, et al., 2009, United States	Behavioural
	Increased hand hygiene compliance with sustained rates greater than 90%.
	Clinical
	MRSA healthcare-associated rate decreased, representing a 54% reduction associated with improved compliance.
	Implementation foundation
	Theoretical and empirical: CDC recommendations and observed low compliance
	Duration
	10 months
	Infection control measure
	Hand hygiene
	Design
	Before and after design

[29]Lee, et al., 2009, Canada	Before and after design	Time series design	
	Educational meetings		Behavioural
	Technology-supported		Non-significant increase in hand hygiene compliance on inpatient medical units. Annual volume of ABHRS purchased by the hospital.
	Implementation foundation		Clinical
	Empirical: SARS outbreak in Toronto in 2003, the Ontario Ministry of Labour mandated an IC education programme for all Mount Sinai Hospital staff		Significant decrease in nosocomial MRSA acquisition rate per 100 admission exposure days. Significant decrease in nosocomial MRSA acquisition rate per 100 unprotected MRSA exposure days.
	Duration		
	1 month		
	Infection control measure		
	Hand hygiene		
	Personal protective equipment		
	Design		
	Before and after design		
	Educational meetings		Behavioural
[30]Liebowitz & Blunt, 2008, United Kingdom	Audit and feedback		Hospital-wide decrease in level of dispensing of intervention drugs. ICU-specific decrease in level of dispensing of intervention drugs.
	Clinical multidisciplinary teams		Clinical
	Implementation foundation		Decrease in level of MRSA-positive screenings (no statistical test). MRSA colonization in screening specimens from high-risk patients decreased. Decrease in level of MRSA-positive screenings (no statistical test).
	Duration		
	2 months		
	Infection control measure		
	Medication		
	Design		
	Time series design		
	Reminders		Behavioural
	Technology-supported		Non-significant decrease of overall AB use. Significant decreases in the use of several antibiotics.
	Implementation foundation		Significant differences between non-antibiotic variables: purchase of chlorhexidine skin preparation increased; the number of ventilator days, purchase of alcohol foam, and the nursing staff ratio decreased.
	Duration		Total fluoroquinolone and levofloxacin use decreased.
[31]Madaras-Kelly, et al., 2006, United States	12 months		Clinical
	Infection control measure		Decrease in nosocomial MRSA infections (not statistically tested).
	Medication		

[32]Miyachi, et al., 2007, Japan	<p>Design</p> <p>Time series design</p> <p>Local opinion leaders</p> <p>Audit and feedback</p> <p>Mass media</p> <p>Implementation foundation</p> <p>Theoretical: prior research on link nurses in large hospitals</p> <p>Duration</p> <p>76 months</p> <p>Infection control measure</p> <p>Hand hygiene</p> <p>Other, non-specified</p> <p>Design</p> <p>Before and after design</p>	<p>Behavioural</p> <p>Significant increase in arithmetic mean of monthly consumption of the liquid soap.</p> <p>Clinical</p> <p>Percentage of MRSA in Staphylococcus Aureus increased.</p> <p>Monthly counts of new MRSA cases dropped in 15 of 25 wards.</p> <p>Significant decrease in the monthly number of inpatient admissions.</p>
	<p>Behavioural</p> <p>Significant reduction of defined daily doses (DDD) of cephalosporins.</p> <p>A clinical audit 12 months after introduction of ASP protocol showed >90% adherence by the physicians (no statistical tests).</p> <p>Clinical</p> <p>Significant decrease of MRSA isolations.</p> <p>Significant correlation between MRSA monthly prevalence rates and reduction of crude DDD use of third-generation cephalosporins.</p> <p>Significant reduction of isolation of MRSA from surgical site infection (SSI) and BSI.</p> <p>Significant decrease in MRSA prevalence among Staphylococcus Aureus associated with SSI.</p> <p>Significant reduction of MRSA prevalence both in Staphylococcus Aureus associated BSI and in the respiratory specimens of patients affected by ventilator-associated pneumonia (VAP) in ICUs.</p>	
[33]Nicastri, et al., 2008, Italy	<p>Educational outreach</p> <p>Clinical multidisciplinary teams</p> <p>Infection control measure</p> <p>Medication</p> <p>Design</p> <p>Time series design</p>	
	<p>Behavioural</p> <p>Post-IT admission culture rate in the telemetry unit was >91% in the ICU and >97% in the IMC unit.</p> <p>Employee satisfaction with the MRSA surveillance protocol was measured by self-assessment survey; 88% of the respondents were “fully satisfied”, the remaining 12% were “satisfied”. (No statistical test use).</p> <p>Increased efficiency of staff time use. Clinical</p> <p>Overall decrease in the rate of MRSA acquisition in the pre-IT period compared with the post-IT period was statistically significant.</p>	
[34]O'Brien, et al., 2008, United States	<p>Educational meetings</p> <p>Reminders</p> <p>Technology-supported</p> <p>Implementation foundation</p> <p>Theoretical: SHEA recommendations</p> <p>Duration</p> <p>12 months</p> <p>Infection control measure</p> <p>Patient screening</p>	

[35]Peterson, et al., 2010, United States	Significant decrease in 2 of 3 unit specific comparisons before and after IT implementation.	
	Design Before and after design	Behavioural Screening compliance increased to >90%, and sustained >90% after programme.
	Distribution of educational materials Educational meetings Educational outreach Local opinion leaders Audit and feedback Reminders Changes in physical structure, facilities and equipment Technology-supported Implementation foundation Theoretical: Institute for Healthcare Improvement's (IHI) five components to MRSA control Duration 24 months Infection control measure Patient screening Design Before and after design	Clinical Decrease in MRSA transmission (from colonization to infection). Decrease in overall MRSA BSIs by the end of the first year. Financial Programme cost represented a net expense of \$15-\$16 per admission. Eliminating 50 infections led to a reduction of nearly \$1,200,000 in medical expenditures, which was at least cost-neutral.
[36]Robert, et al., 2006, France	Behavioural Within groups: medical and nursing staff reported that they knew the MRSA status of patients in 87% of cases in the control period, and in 96% of cases in the intervention period. Medical and nursing records were flagged significantly more often in the intervention period than in the control period. The set of four organizational measures was implemented more frequently in the intervention period than in the control period. The same observation was made when each measure was evaluated separately. When considering only ICUs and rehabilitation units, i.e. wards with MRSA rounds, there was also a significant increase in the implementation of isolation precautions; signs posted on the door more often, use of gowns increased, use of dedicated materials increased, availability of alcohol hand rub increased, and proportion of MRSA patients in private rooms increased. There was no significant increase in the proportion of healthcare workers informed of the MRSA status of patients or in the proportion of flagged records.	
	Distribution of educational materials Reminders Mass media Implementation foundation Theoretical: observational studies indicated that isolation precautions were poorly implemented outside ICUs Duration 3 months Infection control measure Patient isolation Design Before and after design	

[37]Thomas, et al., 2005, States	Reminders	Behavioural Increase in hand hygiene compliance over all units. Participants agreed that, overall, posters had a positive influence on hand hygiene behaviour within the units. More so when poster displayed 'human qualities' or promoted action (instead of just awareness).
	Mass media	
	Implementation foundation	
	Theoretical: research on hand hygiene posters	
	Duration 12 months	
United States	Infection control measure	
	Hand hygiene	
	Design Before and after design	

Chapter 5. Development of the Antibiotic App

This chapter is based on:

Wentzel, J., van Velsen, L., van Limburg, M., de Jong, N., Karreman, J., Hendrix, R., & van Gemert-Pijnen, J.E.W.C. 2014. Participatory eHealth development to support nurses in antimicrobial stewardship. *BMC Medical Informatics and Decision Making*, 14:45.

Abstract

Background: Antimicrobial resistance poses a threat to patient safety worldwide. To stop antimicrobial resistance, Antimicrobial Stewardship Programs (ASPs; programs for optimizing antimicrobial use), need to be implemented. Within these programs, nurses are important actors, as they put antimicrobial treatment into effect. To optimally support nurses in ASPs, they should have access to information that supports them in their preparation, administration, and monitoring tasks. In addition, it should help them to detect possible risks or adverse events associated with antimicrobial therapy. In this formative study, we investigate how nurses' can be supported in ASPs by means of an eHealth intervention that targets their information needs.

Methods: We applied a participatory development approach that involves iterative cycles in which health care workers, mostly nurses, participate. Focus groups, observations, prototype evaluations (via a card sort task and a scenario-based information searching task) and interviews are done with stakeholders (nurses, managers, pharmacist, and microbiologist) on two pulmonary wards of a 1000-bed teaching hospital.

Results: To perform the complex antimicrobial-related tasks well, nurses need to consult various information sources on a myriad of occasions. In addition, the current information infrastructure is unsupportive of ASP-related tasks, mainly because information is not structured to match nurse tasks, is hard to find, out of date, and insufficiently supports awareness. Based our findings, we created a concept for a nurse information application. We attuned the application's functionality, content, and structure to nurse work practice and tasks.

Conclusions: By applying a participatory development approach, we showed that task support is a basic need for nurses. Participatory development proved useful regarding several aspects. First, it allows for combining bottom-up needs (of nurses) and top-down legislations (medical protocols). Second, it enabled us to fragmentize and analyze tasks and to reduce and translate extensive information into task-oriented content. Third, this facilitated a tailored application to support awareness and enhance patient safety. Finally, the involvement of stakeholders created commitment and ownership, and helped to weigh needs from multiple perspectives.

Background

Antimicrobial resistance (AMR) poses a threat to patient safety worldwide. The prudent use of antimicrobials in Antimicrobial Stewardship Programs (ASPs) is propagated as a means to combat AMR. ASPs aim to optimize antimicrobial treatment regarding type of antimicrobial, dose, duration, and route of administration. Formulary-based prescribing, expert (microbiologist, infectiologist) consultation, and scheduled re-evaluation of therapy appropriateness lie at the core of ASPs. In addition to often mentioned key-stakeholders in ASPs (e.g., prescribers, clinical microbiologists, and pharmacists), nurses can make an important contribution, even though their role has not yet been fully defined [1-3]. Nurses spend much time with the patient and put antimicrobial therapy into effect: they prepare, administer, and monitor the effects of antimicrobial treatment and possibly related critical events. To ensure optimal antimicrobial treatment, nurses need to pro-actively alert physicians or relevant experts when problems or abnormalities occur. Decision-making in an ASP is complicated by a multitude of experts and information sources, such as medical protocols, formularies, and local guidelines for antimicrobial use. Since different medical professionals cooperate in ASPs, these sources are not always targeted at nurses or created to support their information need. Therefore, in practice, nurses require adequate information support, especially since their task load is already diverse and high.

To enhance their potential role in ASPs, nurses need adequate training and education on relevant antimicrobial topics, or, as Charani et al. [4] put it: "...understanding of the key principles of microbiology and the unwanted consequences of antimicrobial use". However, at a basic level, information flow and reference sources should be in place and function properly to support nurses' ASP tasks. Thus, good information support, aimed at nurse tasks in antimicrobial use is a prerequisite for nurse involvement in ASP. Information (such as protocols, instructions, and reference books) should be geared to the practical tasks of preparing and administering antimicrobials. This is equally true for more complex tasks involving other medical specialists, such as monitoring patient change and informing, alerting, or alarming others in case of abnormalities.

Technology or eHealth can be used to support education and information sharing in clinical settings. Various studies describe the development of technologies that can improve information supplies to healthcare workers (HCWs) and/or patients, such as a website with protocol-based information, or the utilization of integrated displays on ICUs [5-7]. Specifically aimed at ASPs, research has shown that eHealth holds potential [8]. To support tasks and match with workflow, the technology should fit the users' needs as well as the clinical context in which it is implemented. The Centre for eHealth Research and Disease management (CeHRes) provides a "roadmap": a guideline for the participatory development and implementation of eHealth technology [9]. It offers an approach to systematically anticipate on stakeholders' (e.g., HCWs, management) needs and values,

and to guide design and facilitate implementation. Especially during early stages of development, stakeholder involvement is crucial to create sustainable technologies. A participatory development approach can help to overcome mismatches between work practice and technology. This can be done by checking findings regarding needs, context, and possible design and functionalities with various relevant stakeholders during every stage of development [9].

In this study, we applied the CeHRes-Roadmap [9] to perform the formative research phases of contextual inquiry, value specification, and design evaluations (see Figure 1). Contextual inquiry entailed a twofold investigation: Which information problems do nurses encounter when fulfilling which ASP-associated tasks? The outcomes of this stage served as input for the value specification and design. Thus, first we set out to identify the information needs of nurses performing antibiotic-related tasks in a complex environment. Secondly, we investigated how these needs can be met by eHealth technology.

Methods

Setting

The pulmonary ward (57 beds) of a Dutch 1000-bed teaching hospital participated in this study. At the time of the study, 62 nurses (4.5 FTE) worked at the pulmonary ward. Although some high-risk wards have their own infection control nurses in this hospital, the pulmonary ward does not. This ward receives support from infection control experts to whom wards were assigned by the infection control department (4.4 FTE).

Key stakeholders involved in the development process, besides the researchers, were nurses (a total of 15, who participated in one or several phases), a nurse manager, a clinical microbiologist, a hospital pharmacist, and in later phases, two programmers. In earlier research [10], these stakeholders were identified as key stakeholders. All participants were informed about the study and signed an informed consent form prior to participating. Ethical approval for this study was not necessary according to Dutch law, as participation posed no risk to participants' physical or emotional integrity. The specific procedures per research method are discussed below.

Contextual inquiry

Two consecutive ninety-minute-long focus groups were held with nurses, a nurse manager, and a pharmacist, to establish what information and information sources are used and needed by nurses to carry out their tasks related to antimicrobial use. We aimed at discussing different situations and at creating an image of nurse working situations and needs that is diverse and as complete as possible. Being able to instantly react to what others say,

especially allows for a dynamic discussion that provides the researcher with a broad view on the topic [11].

During the first focus group, conducted by JW and TM, five nurses participated. Four nurses participated during the second focus group, conducted by TM. The nurse manager and pharmacist participated in both focus groups. The nurses had a wide range of work experience, and were reimbursed for their participation with a gift certificate.

Scenarios addressing crucial moments in antimicrobial use were created with a clinical microbiologist and a pharmacist. A scenario was created for each phase in the care process: admitting the patient, preparing/administering antimicrobials, monitoring the effects of treatment, and discharging the patient. An example of a scenario for the admission phase is described in the section below.

Figure 1 CeHRes Roadmap.

The CeHRes Roadmap consists of five iterative development cycles: contextual inquiry, value specification, design, operationalization and summative evaluation.

Example scenario in focus group

Mrs. Jansen (55 years old) was referred from the acute care unit to the chest physician. Mrs. Jansen's temperature is 39 degrees Celsius, she feels clammy and, when listening to her lungs, the physician suspects a lobar pneumonia. Additional diagnostic tests are requested, Mrs. Jansen is admitted to the lung ward, and empirical therapy (Amoxicilline-clavulanate potassium) is started.

During the first focus group, the participants were asked to explain what they would do in each scenario by responding to the questions in the section below. They were asked to write their answers down on post-its, which were then discussed plenary.

Focus group questions to elicit information needs

1. What information do you need?
2. Where would you get this information?
3. At what moment do you need the information?

4. What problems do you encounter regarding the aforementioned questions?

The transcriptions of the audio recordings that were made during the focus groups were independently analyzed by two researchers (JW and TM). A coding scheme was used that was largely based on the focus group setup, and was complemented with additional themes that emerged from the data, utilizing a pragmatic approach [12]. We searched for expressions indicating information types and the context of use, and possible problems when searching for or using information. Adapted from a taxonomy that resulted from similar research [13], we coded the information types into a) patient-specific (all information that applies to one specific patient only such as prescriptions, medical background, or laboratory results) and b) domain-specific information (information that applies throughout the institute or domain, such as reference book information on a disease, or local or national protocols). Differences in coding by the two independent researchers were discussed until agreement was reached. Hereafter, the results were discussed with a pharmacist to check for important missing information.

Value specification

To create an eHealth application concept that targets the information problems that were uncovered in the contextual inquiry, requirements were elicited and prioritized by the stakeholders.

5

Focus group

During the second focus group (see above), participants were shown several examples of how technology can be used to make information available in a task-supporting way. Among others, the website www.MRSA-net.nl [5] was shown as an example of a readily available application for protocol communication. Digital patient chart systems and infection control Wikis were discussed as examples of technologies that are not (yet) available in this hospital. The questions, as summed up in the section below, were asked to elicit a discussion on the examples regarding content, type of technology used, and implementation.

Focus group questions regarding technology needs

1. Is this example useful to you?
2. If so, in what context?
3. If not, why not?
4. What additional information or functionality do you need?

The audio recordings of this part of the focus group were transcribed and translated into design requirements by applying a requirement analysis method [14]. Two independent coders (JW and LvV) analyzed those parts of the transcripts that are related to eHealth

technology, and translated those into underlying values, attributes of needs and actual technology requirements.

Observation

To ensure that the requirements are compatible with actual nursing behavior (practice), we validated them via on-site observations. One researcher (JW) accompanied three nurses during moments that are relevant in antimicrobial therapy: morning drug delivery, lunch-time drug delivery, and patient rounds. The observations lasted four hours. The researcher mostly observed quietly, but asked for clarification when needed. She especially looked for crucial moments of (possible) information technology use and preferred device/source, as the requirements were undecided in these areas. Afterwards, the researcher discussed the observations and requirements with the nurse, the nurse manager, and the other stakeholders, to interpret the observations and to resolve remaining conflicts between requirements. This allowed for the creation of a prioritized list of requirements ensuring the best (foreseeable) match with day-to-day nursing tasks. Based on this list, a working prototype was built.

Design

To assess whether the prototype matches day-to-day practice, a card sorting task, a scenario-based test, and a prototype evaluation were carried out. The assessment was conducted in one-hour individual sessions, with a convenience sample of ten nurses varying in age, work experience, and gender. Each session was guided by one researcher (JW) and audio-recorded. The resulting audio files were summarized.

Card sorting task

Since the information sources that were identified during the contextual inquiry are created by experts, the structure of the information may not support nurses' work practice. We validated the information structure of the prototype via a card sorting task. Card sorting is a design method that can be used to create an information structure for a website or application [15]. During the tasks, each participant was given a set of 42 cards with printed parts of protocols, reference documents and other information documents. Participants were asked to sort the cards in (what they regard as) logical groups, and to name each group while thinking aloud. If necessary (e.g., when only two groups were created such as "relevant" and "irrelevant"), the participant was encouraged to further divide the groups into meaningful subgroups. The resulting sorts were analyzed using cluster analysis with Websort; an online card sorting program (recently taken over by Optimal Workshop, <http://www.optimalworkshop.com>). The data were analyzed to determine the final information architecture, based on various (iterative) steps [16]: a) percentage of item agreement between the participants (how often two items were placed in one group), b) dendrogram output (visualizations of possible groups, based on item

agreement) and c) logical interpretation by the researcher (JW), to make sure no illogical or one-item groups exist due to misinterpretation of cards. Average agreement percentages per final created group were calculated.

Information searching task

After the card-sorting task, a scenario-based information searching task was conducted to assess whether the prototype fits with current information use and work practice. First, the prototype was introduced briefly. Then, the nurse was given a scenario and asked to resolve it by searching for information, while using the prototype and thinking aloud. The scenarios addressed possible critical moments in correct antimicrobial use such as possible liquid restrictions of patient, drug-drug interactions, correct preparation and concentration, side effects and renal functioning. An example of a scenario is shown in the subsection below.

Example scenario as used in information searching task

A patient (male, 59 years old) is admitted to the hospital because he is hypoxic, has large infiltrates on his x-thorax, and the rapid test indicates pneumocystis. Since quite some time, the patient takes Prednison for leukemia. The physician prescribes 1960 milligrams of co-trimoxazol, twice a day. In the past, the patient suffered a deep-venous thrombosis in his leg, for which he is still taking Coumarine. The patient also takes Lasix for cardiomyopathy.

Prototype evaluation

The session was concluded with a short evaluation of the prototype, consisting of their first impression and comments on the look and feel and content. We also asked for missing features and other thoughts on functionality and implementation in the care process. Regarding the scenario tests and prototype evaluation we merely noted if problems or concrete verbalizations of problem arises or an idea is expressed may not be representative of its importance [14]. The resulting changes and additions to the requirements were discussed with the other stakeholders (manager, microbiologist, pharmacist, and programmers), to decide on the priority of proposed adjustments for the final version of the application.

Results

Contextual inquiry

Information need

The focus group results show that nurses need patient-specific information regarding medical history and treatment such as previous admissions, allergies and readily received

medications/treatment. Also, practical patient-specific information is needed such as the patient's identity, the room assigned to a patient, and patient transport arrangements. For example, one of the participants wrote down the following two questions that arose regarding the preparation and administration scenario: *"how often [should we give] antibiotics per day?"* and *"Is Mrs. Jansen allergic to something"*. During the discussion, one nurse explained her information need as written on her post-it: *"Well, first [I need] basic information such as: who this patient is, why the patient is admitted, so, the reason of admittance. What antibiotic is started, how often per day. How many milligrams"* (Nurse 6). For a full list of all patient-related information needs we refer to Additional file 1. Domain-specific information needs regarding the antimicrobial treatment of patients consist of several types of information. For example: *"And what else do you do: the checks, you need to know about the side effects and whether the medication can be given with other medications, a combination"* (Nurse 5). In sum, the following types of information were mentioned:

- background information about a disease that requires antimicrobial treatment or about an antimicrobial (such as characteristics or standard dose);
- instructions on how to dissolve and administer an antimicrobial;
- information on the availability of an antimicrobial (on the ward); and
- information on monitoring such as acute effects, side effects, interactions, and safety of combinations of medicines, possibility of administering several medicines via one intravenous line, and other monitoring points of attention.

Instructions are always used when preparing and administering antimicrobials. However, other domain-specific information needs arise occasionally, especially when caring for patients who are treated with antimicrobials that are not used often on that ward.

Information sources

Patient-specific and domain-specific information, as described above, are sought from various sources. Some of these sources are used interchangeably, and nurses have indicated that the exact situation, the available search time, and ease of retrieval which source is chosen. Many sources are needed recurrently and are not confined to one single task or phase in the care process. With regard to the scenario of administering antimicrobials, one nurse states: *"Now I would get it [the information] from the electronic prescription system, because that holds my assignment. So where do you get it? From my computer"* (Nurse 1). Patient-specific information is sought in the following paper or electronic sources: the transferal document of the Accident & Emergency unit or admission office, the patient chart, the (electronic) patient record, the general practitioner's patient record, the electronic prescription system, old admission documents, the digital bed schedule, transfer notes, the assignment sheet, and test results. Domain-specific information is retrieved from protocols in the document management system, the

intranet, pharmacological reference books, the hospital's pharmacy information system, drug instruction leaflets, the electronic prescription system, the assignment sheet, and pharmacy stock lists. For example, a nurse indicates that at the ward they use the drug instruction leaflet for domain specific information: *"You can always find it in the drug instruction leaflet"* (Nurse 2). Besides documents or administration, nurses consult the following persons for patient-specific or domain-specific information: the patient himself/herself, the patient's family, the secretary, the pharmacist, the physician or resident, the general practitioner, the coordination office for admission and discharge, the physiotherapist, the dietician, or a colleague. A nurse explains regarding asking colleagues: *"Or ask a colleague who does have experience with it. That is also possible of course"* (Nurse 5).

Work context

Much variation exists regarding the moment in the care process and the context in which information is used. Most information types (such as patient background or status) are used frequently, repeatedly, and throughout the care process, with some exceptions for moment-specific information needs such as instructions for preparing antimicrobials, or information regarding continuation of care at home after discharge.

Problems with information search

The main problems nurses encounter during information use arise in finding the information, both in terms searching for information digitally. Nurses report that sometimes, information is not available, for example regarding information on intravenous administration: *"It is located in Pharmacy Net [intranet pharmacy site]. It is not always entirely complete"* (Nurse 3). Information system user-friendliness is also a problem: *"Yes, the document management system. Try to find something in there..."* (Nurse 1). In addition, time constraints hinder information-finding, as illustrated by the following remarks: *"Searching simply costs a lot of time"* (Nurse 3). As a result, nurses may prefer to rely on their own or their colleagues' knowledge. The results show that nurses have many instances of patient-specific and domain-specific information needs, and that they turn to a wide variety of sources in order to find the information. Having relevant and usable information at their disposal is important. Yet, the nurses currently lack information sources that are quickly accessible, easy to use, and thus genuinely supportive of their tasks. This non-supportive information infrastructure can stand in the way of nurses taking up, and even wanting to take up an active role in antimicrobial stewardship.

Value specification

Based on the requirements elicitation procedure, the following values were identified from the focus group results: easy access to information, useful and relevant information, and ease of use of information. This is illustrated by the following quote: *"You need to have it*

directly at hand whenever you need it, that you can click on it and reach the right page directly (...) that you don't have to search for too long" (Nurse 5). In addition, after evaluating these values with nurse management, additional values emerged: (an improvement in) quality of care, and interoperability or compatibility with systems that are currently in use. The requirements resulting from the requirement analysis are classified into a) content, b) technical, and c) device (or implementation) requirements. Table 1 shows examples of participant quotes, attributes and resulting requirements. Some example requirements are that the application should provide information from the patient file (medical history, diagnosis, received treatment, test results, etc.) and that it should provide all (antimicrobial related) information via one interface. For a complete overview of resulting requirements, we refer to Additional file 2. Based on the requirements, a mockup was created to roughly visualize a possible design and to communicate ideas to the design team and stakeholders. Figure 2 shows the mock-up of the principal screen where different types of information can be accessed.

Table 1 Example of quotes and requirements

Quote	Attribute ("voice of the customer")	Requirement
<i>"but you would still have to gather it, search for it. In the end (...)"</i> —Pharmacist <i>"(...) in one spot. All in one spot."</i> (Nurse 1)	One stop portal for information	All information is accessible via one interface or starting point.
<i>"So I think you would really have to carry it around with you, but then the question is, how to carry it precisely."</i> (Nurse 1) <i>"It should fit into a pocket."</i> (Nurse 5)	Mobility of information	Size of device should be bigger than smartphone, but small enough to be carried around easily/fit in pockets.
<i>"It should be possible, in X-care there is a diagnosis for admission. It should be possible that that is linked, that when you click on the diagnosis, you get general information on pneumonia, just to give an example. But only general information: what it is, how it is treated."</i> (Nurse 6)	One stop portal for information	The system offers protocols and general information on diseases.

Observations

The observations indicate that several requirements do not optimally meet the two values: "ease of use" and "useful, relevant information" due to practical, organizational, or technical issues. For example, scanning the patient barcode appeared to be a user-unfriendly task, prone to work around methods. Therefore, the requirement of disclosing patient information via a barcode scan lost its priority. Another issue was that nurses use a PC on wheels during drug administration. The application should therefore run on a PC as

Figure 2 Mock-up of information application dashboard.
In this mock-up, the general information was structured per antimicrobial in dashboard style.

well as on mobile phones or tablets, as nurses prefer looking up information on a PC when they are already using that. However, as smartphones or tablets are easier to carry around, the application should function on those as well. Based on the observations, the design team decided that several requirements were dropped or postponed for the initial prototype. For example, disclosing patient-specific information and linking the concerning databases in one application is important, but this requirement was postponed because it is too costly and complicated for the prototype. This way, a prototype can be developed to create the necessary buy-in from the range of stakeholders (physicians, pharmacists, microbiologists etc.) who are associated with the supply and maintenance of information, implementation, and technical support of the various information systems involved.

Based on the outcomes, a working prototype was developed that centralizes domain-specific antimicrobial-related information from different sources. It is web-based, enabling access via various devices (pc, tablet, smartphone) in different settings. After selecting the antimicrobial, the application displays different options for the types of task-supporting information in one single interface.

Design

Card sorting task

Based on the card-sorts, an information structure for the application was identified. The sixteen-group solution as provided by the analysis program was deemed most applicable, regarding face validity of the groups (least illogical combinations). To prevent groups from being too small and to match closely related content, we merged some groups, which

resulted in the following groups: dosage; preparation; administration; properties; acute responses and warnings; interactions, contra-indications, and compatibility with other drugs; and medical/for the physician. Item agreement percentages as they resulted from the card sort analyses are displayed in Table 2. On average, agreement on placing two items in one group ranges from 28% to 60%. This shows that some items were placed in groups that the participants did not agree on, and that some items were originally placed

Table II Card sort item agreement per group

Group	Number of cards	Average agreement (%) of two cards in this group	Example
Dosage	2	60	Card (dosage source 1) and card (dosage source 2) were placed in the same group by 60% of the participants.
Preparation	7	57	Card "Pump protocol" and card "Final concentration of solution" were placed in the same group by 10% of the participants.
Administration	10	55	Card "Administration route" and card "Administration per perfusion" were placed in the same group by 30% of the participants.
Properties	5	28	Card "Extra checkups" and card "Blood tests" were placed in the same group by 80% of the participants.
Acute responses and Warnings	6	39	Card "Side effects" and card "Warnings and precautions" were placed in the same group by 40% of the participants.
Interactions, indications, Compatibility with other drugs	5	55	Card "Contra indications" and card "Interactions" were placed in the same group by 80% of the participants.
Medical/for physician	7	60	Card "Kinetic properties" and card "Available products" were placed in the same group by 50% of the participants.

in isolated categories. This was especially the case in the 'properties' (28%) and 'acute responses and warnings' (39%) groups. Safety was added as a group based on participant comments after the card sort. Furthermore, ASP experts (clinical microbiologist and pharmacist) suggested additional content and, thus, additional groups. The groups were divided into five categories for the dashboard-style overview page: application, precautions/details, background information, safety, and medical information/other.

Where groups had to be merged, original card-sorting group results were kept as subcategories (buttons in the overview page) as much as possible.

Information searching task and prototype evaluation

Based on the scenario-based searching tasks and prototype evaluation, various suggestions for prototype improvement and the implementation plan were identified (here, we focus on the variety of suggestions, not how often they came up). Table 3 gives an overview of the results. Besides appraisal and concrete suggestions for improvement regarding content, structure, functionality, layout and implementation, more fundamental remarks on task perception arose. The results show that the role perception of nursing in ASPs is undefined regarding the complex aspects of nurse tasks: monitoring of patient progress, checking for critical events, and alerting or alarming others in case of alarming changes in patient status.

The information search task and prototype evaluation results were discussed with stakeholders to assess the feasibility from a medical, organizational, and technical perspective. This resulted in the rejection of some requirements, such as the expansion of the content to other types of medications (since that would render the project too large for this phase). The finalization of the application and concurring implementation strategy were adjusted to these outcomes and stakeholder discussions. For example, in instructional meetings extra attention was paid to task and role views of nurses in an ASP, because there was ambiguity on this issue. A screenshot of the final application as it is implemented and tested on efficacy can be seen in Figure 3.

Figure 3 Screenshot of the information application.

The application consists of buttons, grouped into categories corresponding to the card sort results, with minor changes.

Table III Re-design results based on scenario tests and prototype evaluation

Suggestion description	Example quotes	# (unique) results
Content : Remarks or events that indicate what information, and how much information should or should not be incorporated in the app. Remarks or events that indicate the usefulness or importance of certain content	<i>"Protective measures, is it already in the app? Or in a protocol? (...) For your own protection" (Nurse 3).</i> <i>"We are talking about antibiotics, but would it be possible to use this for other medications as well?" (Nurse 5).</i>	41
Structure: Remarks or events that indicate how information should be structured or displayed	<i>"For example, the Farmacotherapeutisch Kompas [website with pharmaceutical information] is very nice, but too complicated. Difficult to understand, at a glance. And this [the app] is just, this is very nice at a glance" (Nurse 10).</i> <i>"This is clear, everything I need is on this page" (Nurse 2).</i> <i>"Here for example, it is a lot of text. It would be better to make more subheadings or something" (Nurse 5).</i>	13
Layout: Remarks about the layout; what the app looks like	<i>"That it looks very good" (Nurse 10).</i>	5
Functionality: Remarks or events that indicate what the app should or should not be able to do. Remarks or events that indicate how it functions/should function	<i>"I would print pump protocols. I do that sometimes, I put them in the patient file (...) maybe it is me, if I would have a nice iPad, I would find that convenient as well" (Nurse 3).</i>	13
Task perception: Remarks on, or events that describe current tasks or work methods, and remarks or events that indicate perception of what own task or physician tasks constitute	<i>"We can have a look at it, but we cannot do anything about it. In principle, the physician is responsible for lab results. Sometimes we alert the physician when we see it, but we do not pay attention to these things, with antibiotics" (Nurse 1).</i> <i>"It is no tour task, really, but I think, you all work with people for people, so (...) you should be able to do something about it (...) because we are the ones, normally, who administer it." (Nurse 6).</i>	22
Implementation: Remarks or events that indicate how the app relates to the current information infrastructure or how it would fit into current work processes	<i>"I think this is something for the physician, whether it is a small-spectrum or broad-spectrum antibiotic (...) for us, preparation and how you should administer it is important" (Nurse 2).</i> <i>"We are doing a lot on the computer already, I think it would best to have everything in one place, that you are with the patient and [have the information at hand]. We are heading that way anyway" (Nurse 9).</i>	8

Discussion

In this study on nurse information support in ASPs, we identified and studied the main problem areas (scattered sources and task-supporting infrastructure), by participatory development with the target group (nurses) as well as other stakeholders. Weighing user needs against the limitations caused by the context and stakeholder needs guided decision-making in the development process. This broad view is likely to contribute to a successful implementation [17]. In this study, the use of different methods and continuous feedback about results to the participants gained understanding of work practice (needs, tasks) and elicited requirements for the technology. At the same time, other stakeholders, such as managers and technology experts, were consulted to prioritize and operationalize the requirements. Besides elicitation of and decisions on functional requirements (what the technology should be able to do) and design requirements (what interfaces should look like and how they should be structured to support tasks), the dynamic of our approach resulted in insight regarding information needs, task perception, and implementation.

Nurse involvement in ASPs relies on being able to correctly perform basic antimicrobial-related tasks such as preparing, administering, checking and monitoring of antimicrobial use. In addition recognizing moments for treatment optimization is crucial. In this study we identified the information needs of nurses to perform these tasks adequately, and the problems that they are currently facing: a multitude of scattered information sources that are non-supportive. This complex work context is also visible in more general nursing settings concerning information use for drug-related tasks [13,18,19]. Nurses often need to interrupt their activities to search for information. The search is unclear, but our observations indicate that the search is likely to be postponed (or dismissed altogether), possibly compromising patient care. Therefore, a good understanding of (work) practice and related problems is a first step in eHealth development. Based on our contextual inquiry we argue that for the improved use and monitoring of antimicrobials by nurses, supportive technology needs to integrate information from different (expert-driven) sources in a user-centered, task-supporting way. Integration of different sources into one display alone probably does not suffice and restructuring or even re-creating (including wording and phrasing of) information sources to specifically match nurses' tasks may be necessary.

If nurses are to adopt an active role in ASP, they need background information about the basic principles of antimicrobials and antimicrobial stewardship [4]. However, we first need to focus on information provision at a more fundamental level, namely the information and instructions that support the tasks of nurses working with antimicrobials. In line with our results there are many occasions during their day-to-day work when nurses need to have quick and easy access to information about drug therapy, as Cogdill demonstrated [18]. Optimizing the information flow regarding drug therapy is a crucial first

step. In addition, research shows that nurses acquire information and knowledge about drug administration by looking it up in written sources, or by asking colleagues, and not via formal training [18,19]. Memorizing all instructions and background information on all types of medications would be impossible. During the course of our research stakeholders maintained that even though knowledge should be present, it could also be implicitly acquired. Thus, reliable and easily accessible information is crucial for nurses as it may be a more important source than previously acquired knowledge or training [19]. We showed how this (often expert-based) information can be matched to work practice by continuous involvement of participants (users and other stakeholders) during eHealth development.

The unexpected finding regarding nurse role perception leads us to conclude that our approach may be especially useful in development processes where new programs or work methods are introduced, instead of merely a new technology. Target group involvement during formative research, combined with stakeholder checks or evaluations, rendered important results; it opened a discussion the technology (e.g., ambiguity on what content should be aimed at nurses) and helped to adjust the technology to work practice.

We started this study with the idea that nurse support in ASPs relies on good information support regarding antibiotics, as our first explorations into ASP support tools indicated [10]. The scenario-based task results of the study described in this article showed that providing (easy accessible) information on (for example) optimal dosage or drug-drug interactions, does—in itself—not trigger the nurse to be more proactive in signaling problems in these areas, even though the nurses did acknowledge their signaling potential. To support these implicit roles, we plan further studies. We aim to capture expert and nurse opinions to shape and concretize these roles, and develop adequate (technology) support, consisting of checklists or decision aids as these are promising in other areas [20].

Limitations

Although our results regarding information needs are comparable to findings in other studies, as described above, the results may not be fully generalizable to other wards or specialisms. Given the stakeholder-centered approach we applied, this is to some extent inevitable. To ensure a good fit between users, the organization, and the technology, one needs to actively involve stakeholders in the development process, and the qualitative and iterative nature of the methods that were used imply small research samples. However, small samples can produce valuable results when applying user-centered methods such as card sorts and scenario-based user tests [21,22], and we were able to perform multiple iterations in the development process. We tried to address issues of representativeness by involving participants with varying background and work experience in the research. Another possible limitation of the study is a current lack of insight into uptake and effectiveness of the application on actual work practice. Even though the user tests did hint towards satisfaction with this way of information searching and representation, the effects

of the application on work efficiency, medication errors, and changes in nurse performance regarding antimicrobial stewardship (increased awareness, alarming, more appropriate antimicrobial therapy) are unknown. Therefore, the release version of the application will be tested in a six-month pilot study that focuses on effects on information behavior, satisfaction, and nurse behavior in antimicrobial stewardship. Also, stakeholders are consulted to create business models for the application in order to determine an implementation strategy that reaches beyond the pilot ward.

Conclusions

This article shows how participatory development can be applied to study and innovate health care. Via this approach, we found that nurses can be valuable contributors to ASPs, provided their information needs are met. The participatory development methods allowed us to explore this novel concept matching top-down (expert-based views, medical protocols) and bottom-up (nurses' information needs) perspectives in a complex information context. The requirement elicitation methods and evaluations of the concept rendered results that have implications reaching beyond technology design: The methods support and shape health care innovation and, in this case, resulted in co-creation of technology, generated commitment, and aided antimicrobial stewardship by nurses.

Additional files

Additional file 1: Nurses' patient-specific antimicrobial information needs.

Additional file 2: Information Application Requirements.

Accessible via <http://www.biomedcentral.com/1472-6947/14/45/additional>

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Chapter 6. Antibiotic App Effects

This chapter is based on:

Wentzel, J., van Drie-Pierik, R., Nijdam, L., Geesing, J., Sanderman, R., & van Gemert-Pijnen, J.E.W.C. (submitted). Antibiotic information app offers nurses quick support.

In review in *American journal of Infection Control*, revisions will be submitted in October 2015

Abstract

Background: Nurses work in complex medical settings with a high cognitive task load, which asks for easily accessible information that is aimed at task support and requires minimal additional cognitive load. Nurses can be crucial contributors to antimicrobial stewardship and interventions aimed at improving antimicrobial use, but nurse empowerment in antimicrobial stewardship contributes to their job complexity. An information application (app) was developed to support nurses in ASP. In this study, we tested information support efficiency, effectiveness, and user satisfaction regarding this antibiotic information app for nurses.

Methods: In this pilot study, changes in user satisfaction regarding information support, safety attitudes, and antibiotic stewardship behavior were assessed with a questionnaire. At baseline 28 nurses completed the questionnaire sent to them via email; after the pilot 18 nurses participated. Randomized scenario-based user tests were carried out to assess app efficiency and effectiveness at baseline ($n=16$), in a control condition without the app ($n=17$) and a condition with the app ($n=17$).

Results: Significant information situation improvements were found regarding task support ($p=.041$), reliability ($p=.004$), unobtrusiveness ($p=.000$), relevance ($p=.002$), user friendliness ($p=.000$), speed, and hyperlinks ($p=.001$). In addition, an improvement in communication was observed regarding nurse-physician understanding ($p=.034$). With the app, nurses solved the scenarios faster than without it.

Discussion: The human-centered design approach and persuasive strategy of task support were effective in creating a more positive user experience regarding antibiotic-related information, and reducing time needed to find information, as the questionnaire and scenario test results show. The lack of effects (questionnaire) and clear improvements in quality of stewardship-related behaviors (solutions of scenario tests) show that empowerment of nurses in antimicrobial stewardship asks for active education strategies and interventions that improve nurses' task perceptions. Thus, to reinforce seeking and applying information via a task-support could contribute to prudent antibiotic use in terms of efficiency. However, eliciting new behavior (more pro-active checking, monitoring, the emancipative tasks of nurses) needs other persuasive strategies; unknown topics are not accessed and scenarios focusing on specific stewardship-tasks cause confusion and (some) resistance, even though information is easily available.

Introduction

Nurses often work in complex medical settings and are required to check and act upon various information flows and actual patient progress [1, 2]. This results in a high cognitive load, with risks of errors and suboptimal care [3]. As more and more information and communication systems are in place to provide up-to-date information [4], integrated displays facilitate the timely processing and interpretation of information in clinical settings [5]. With such systems, it is especially important that the design and content are adjusted to the target group with respect to their cognitive tasks and processes and the specific (clinical) setting in which they are used [6].

Technology can thus be supportive of health care processes in clinical settings, partially because it has an ability to support or reinforce behavior [7]. It may be especially assistive in overcoming the challenges with guideline and clinical protocol adherence, for example by applying persuasive technology [8]. The key goal of persuasive technology is to motivate users to reach goals via technology through persuasion and not coercion or deception [8]. The Persuasive Systems Design (PSD) model, proposed by Oinas-Kukkonen describes various strategies that can make technology persuasive [8]. These strategies include supporting primary tasks (facilitating core tasks that need to be performed via the technology) and offering dialogue support (easy interaction with and via the system). In addition system credibility support (offering cues of trustworthiness and reliability of the system and its contents) and offering social support (creating a motivation to use the system via social cues such as comparisons or observations) are persuasive strategies [8]. The PSD model has been applied to facilitate health behaviors of patients, but it has shown to hold its value in enabling health care workers (HCWs) to perform tasks more efficiently and pleasurable [9].

Technology, especially when it is set out to be persuasive, can have a strong potential for supporting nurses during their daily tasks. In this study, we focus on the information situation regarding antimicrobial use, as part of the implementation of an Antimicrobial Stewardship Program (ASP). ASPs aim to improve antimicrobial use in clinical settings by offering a bundle of interventions aimed at the key stakeholders (prescribers, pharmacists, clinical microbiologists) [10]. These improvements in antimicrobial use are needed to control the increase in antimicrobial resistance (AMR). This has become a serious threat to patient safety, because pathogens that have become resistant to antimicrobials can cause infections that are difficult or impossible to treat [11]. Especially in clinical settings, where patients' health is already weak and bacteria can be transferred easily among patients, AMR is a severe problem. Besides a need for new antimicrobials (for which development takes much time and money), experts underline the importance of using antimicrobials only when it is really necessary, using only the appropriate type, in appropriate dosage, duration, and model [10]. Antimicrobial

Stewardship Programs thus usually include strategies that inform involved HCWs (such as physicians) about preferred antimicrobials to use in certain situations via guidelines or protocols and facilitate information sharing regarding symptoms, patient status, lab results, and local resistance patterns in order to timely adjust treatment [12].

The role of nurses in ASPs is not often addressed or clear. Nurses have been proposed as important actors in care involving antimicrobial therapy [13-15]. To ensure antimicrobial therapy is appropriate, timely adjustment of therapy regarding dose, duration, and type is important. For this, diagnostic results and changes in current patient status need to be considered. Nurses are important actors in ASP as they spend much time with the patient, are the ones that put antimicrobial therapy into practice, and monitor the effects on the patient. In case of (sudden) changes or abnormalities, nurses are the eyes and ears of the physician and have great potential in recognizing suboptimal antibiotic therapy. From previous research we learned that in order to be able to take up this proactive role, nurses need to have access to and be supported by information [16]. To address this information need the Antibiotic App was developed; an application that offers centralized information on antibiotics, based on human-centered design (HCD) [17]. In this application, readily available information sources are integrated into one system, offering the nurse a quick way to find information. With the app, nurses can select an antibiotic and access the information that matches his/her information need, by selecting the corresponding button from a dashboard (see Fig 1).

Information supporting practical tasks (e.g., instructions for administering or preparing parenteral antibiotics) and background information (e.g., information on side effects, allergies, or the working mechanisms of the antibiotic) are available via the application (see Figure 2). The application is available without login via the nurses' medication registration system that is used during medication rounds. It relies most on primary task support as a persuasive strategy, as was previously confirmed in analyses of user evaluations of the application [17].

Objective

In this pilot study, we evaluate the Antibiotic App regarding its contribution to user satisfaction with antibiotic information, effectiveness, and efficiency. We expect that the information situation with the app, that was created via HCD [16], has improved usability and user satisfaction as compared to pre-implementation information sources. As a result, we expect the app to support nurses in their antimicrobial-related tasks by making information easier and faster to find, and thereby, better to apply. The information support that the app provides should translate to a better overall appreciation of the information situation, improved communication and teamwork, and is expected to also influence antimicrobial stewardship related behaviors (alerting and commenting on sub-optimal antibiotic therapy).

Figure 1. Screenshot of an overview page

A: Open search field to search an antibiotic, B: Drop-down menu to select an antibiotic, C: Open search field to search within the pages of the selected antibiotic, D: information blocks, arranged by task and/or relevance. (originally in Dutch)

Figure 2. Screenshot of a target page

A: Back-button B: print and email buttons, C: Search field, D: Breadcrumb trail, E: Instruction block on administration, F: Source with link, G: Information on last update of the information block. (originally in Dutch)

Methods

To assess app effectiveness, efficiency and user satisfaction regarding information support, we applied various methods. A *questionnaire* was created to measure pre- and post-implementation satisfaction with and usability of information sources, communication and teamwork, safety behavior, and antimicrobial stewardship related behavior. In addition, to assess whether nurses are better able to find and apply information more efficiently with the app than without the app, we conducted scenario-based user tests.

Design and procedure

All baseline measurements were conducted before the app was introduced at the wards via clinical lessons and distribution of fact sheets and flyers. The setup of the pilot period and timing of measurements is depicted in Figure 3. The application was introduced as an addition to readily available information sources and nurses were free to use the information source they preferred (application or regular) during the pilot period. All post-implementation measurements were done eight months after introducing the application at the wards, thus giving the nurses ample opportunity to use the application and if preferred, integrate it into their daily work practice. App log data of this pilot period shows steady use [18]. The long pilot period prior to post-implementation measurements diminishes possible effects due to the novelty of the system as compared to the usual information sources.

Figure 3. Pilot design

A pre- and post-implementation questionnaire was sent via email to all nurses of the wards to assess satisfaction communication and teamwork, safety behavior and ASP related behavior. Up to two reminders were sent via email in case of non-response.

In addition to the questionnaire, scenario-based tests were conducted. These tests included a baseline measurement and measurements in (randomized) intervention and control groups in post-implementation measurements. Every session took place at the nurse's ward, in an office or activity room, where at least one computer was present (which the nurse normally also uses). Every nurse was instructed about the test. It was stressed that search capacities of individuals were not the focus of this study and that 'wrong' answers or actions did not exist. Hereafter, the audio recorder was started, the nurse was handed out a sheet with the scenarios. Then, the nurse was asked to read his/her first scenario aloud. The nurses were asked to do what they would normally do in each scenario to find a solution, and to 'think aloud' while doing this. During baseline measurements and in the control condition nurses could use all information sources that they had available before the application was introduced. In the intervention condition, only the Antibiotic Application could be used. After completing three scenarios, a short interview was conducted. In this interview, the nurse was asked for a reflection on whether the scenario was realistic, and how he/she experienced resolving it. Each individual session lasted for about thirty minutes.

The university's ethical committee gave ethical clearance for this study. All participants of the scenario tests signed an informed consent form. All participants received information about the study prior to participating and were informed about their right to withdraw at any moment.

Setting

In this pilot, two lung wards of a local 1000-bed teaching hospital participated. The wards have total of 57 beds. During the eight-month pilot phase, on average, a total of 62 nurses (45 FTE) worked at the wards.

Participants

In the scenario-based tests, a convenience sample of 16 nurses participated in baseline measurements (use of pre-implementation information sources). After an 8-month pilot period, a convenience sample of 34 nurses participated and was randomized into two conditions: intervention (use of the application, $n=17$) and control (use of regular information sources only, $n=17$). Of the nurses who participated in the baseline measurements, 7 participated during post-measurements ($n=4$ in experimental condition, $n=3$ control).

All nurses of the two participating wards ($N=62$) were invited to complete a pre- and post-implementation questionnaire. A total of 28 nurses (45%) participated in the pre-implementation questionnaire; 18 nurses (29%) filled out the post-implementation questionnaire. Of these participants, nine nurses filled out both pre- and post-questionnaires.

Table 1. Participant characteristics

	Scenario-based tests*	Questionnaire
N	50	45
Mean age	31.9	37.7
% woman	83.7	87
Years working on ward	5.4	7.7
Years working as a nurse	9.1	12.6

*Data of one participant could not be used because of damaged audio file: characteristics of this participant are not included here or in further analyses.

Table 1 depicts the characteristics of all participants per research method. No significant differences per group (baseline, control, and intervention in the scenario-based tests and pre- and post-measurement in the questionnaire) were found, except for time working at the ward in the scenario-based tests: 5.3 years, 4.2 years, and 6.9 years at baseline, control and intervention, respectively.

Materials

As it was our goal to assess whether the app contributes to the availability and usability of information for nurses, and because nurses can choose from different information sources to look up information, we assessed the overall satisfaction and usability of information sources as opposed to one particular application or information source. The Perceived Persuasiveness Questionnaire (PPQ) [19, 20] and five subscales (Relevance, User friendliness, Hyperlinks, and Speed) of the Website Usability Questionnaire (WEQ) [21] were administered, both adapted to measure available antibiotic information sources in general, as opposed to one particular information source. User satisfaction regarding the Antibiotic App in specific has been assessed and reported elsewhere [22]. To assess communication and teamwork, the subscales Openness, Accuracy, and Understanding of the ICU Nurse Physician Questionnaire [23] and subscale Teamwork Climate of the Safety Attitudes Questionnaire (SAQ) [24] were administered. To our knowledge, no instrument to measure antimicrobial stewardship behavior among nurses exists. Therefore, we formulated four items that reflect the monitoring and alerting role of nurses in ASP: I give suggestions to physicians about the antibiotic treatment patients receive; When I have a feeling that something is not right about the antibiotic therapy of a patient, I discuss this with the physician; It is unusual to give physicians suggestions about the treatment patients receive; Physicians ask nurses for advice.

For the scenario-based tests, nine scenarios were created together with pharmacists (RvD, LN), to depict situations that are relevant concerning antimicrobial stewardship that (can) occur during nurses' work. In some cases, the scenario concerned a topic that would eventually result in alerting of the physician and discussing the right course of action with him/her (e.g., noticing and checking up on an inadequate dosage

when a patient is overweight). Other scenarios focused on nurse tasks that do not involve direct physician end responsibility (e.g., preparing the right concentration of intravenous antibiotics).

Analyses

All questionnaire items were measured on 5-point Likert scales. Negatively formulated items were recoded. As the number of items per scale differs, average sum scores were calculated per (sub) scale. Concerning the four ASP-related items we report average (per condition) item scores. Differences between groups were statistically tested via independent samples T-tests, using SPSS Statistics 22.

To assess scenario-test outcomes, time needed for search was determined in seconds, based on the audio file records. In a few cases, no search was performed because the nurse immediately resolved the scenario (correctly or not) with ready knowledge, or because he/she directly gave up or indicated they would call in for help instantly. In these cases, no time was recorded. In all other scenario outcomes, time in seconds was calculated from right after reading the scenario aloud (start) until the nurse verbalized his/her solution to the scenario (stop). Second, we assessed per scenario whether the nurse found the right information, in the right source, and drew a correct conclusion from it. The following possible scenario outcomes were scored:

1. Wrong information was found by nurse, wrong answer (or no answer) given
2. Search for information was done, no information was found, nurse gave up
3. Nurse instantly gave up (did not initiate a search) and/or immediately called for a physician or pharmacist (in some cases, calling in experts may be better than trying to resolve something you really do not understand)
4. Nurse initiates search, but without success (does not understand or localizes the necessary information), then calls a physician or pharmacist or colleague for assistance.
5. Nurse provides wrong solution to scenario, but found the correct information on which this (wrong) solution is based.
6. Nurse provides the correct solution to the scenario, but bases it on an incorrect search (wrong information sought, or without searching for information)
7. Nurse provides the right solution to the scenario, after searching, finding, and interpreting the information.

Differences between the intervention and control group were assessed by performing independent samples T-tests (time needed to solve a scenario) using SPSS Statistics 22, and by comparing bar charts of scenario outcomes per condition.

Results

Questionnaire - The questionnaire outcomes give insight into the nurses' perception of their information situation. Improvements in user experience as expressed in the mean subscale scores of the PPQ and WEQ were found among all subscales (see Table 2), these improvements were significant in Task support, Reliability, Unobtrusiveness, Relevance, User friendliness, Speed, and Hyperlinks (see Table 2). Especially the time participants perceive it generally costs to find information (Speed) improved, from a 2.4 to 3.7 mean score (on a 1-5 scale). Safety related scales (Nurse-Physician Questionnaire, SAQ) showed improvements in all mean scores, but only Understanding significantly improved from 3.2 to 3.4. Lastly, mean item scores on the ASP behavior items deteriorated or stayed equal, none of these means differed significantly between pre-and post-measurement.

Table II. Questionnaire results

	Subdomain or scale (number of items)*	Pre- implementation (n= 29)	Post- implementation (n=18)	P- value
PPQ	Task support (2)	3.9 (0.7)	4.3 (0.4)	.041
	Reliability (1)	3.7 (0.9)	4.3 (0.5)	.004
	Persuasiveness (3)	3.8 (0.7)	3.9 (0.4)	n.s.
	Unobtrusiveness (4)	2.8 (0.7)	3.7 (0.5)	.000
WEQ	Relevance (3)	3.6 (0.5)	4.1 (0.4)	.002
	User friendliness (3)	2.9 (0.4)	3.3 (0.2)	.000
	Speed (2)	2.4 (0.8)	3.7 (0.7)	.000
	Hyperlinks (2)	3.4 (0.6)	4.0 (0.6)	.001
ICU Nurse-Physician Communication Scale	Openness (4)	3.7 (0.4)	3.8 (0.4)	n.s.
	Accuracy (5)	3.4 (0.4)	3.6 (0.4)	n.s.
	Understanding (8)	3.2 (0.4)	3.4 (0.4)	.034
SAQ	Teamwork (14)	3.8 (0.4)	3.9 (0.3)	n.s.
Antibiotic Stewardship Behavior	Make suggestions about antibiotic treatment	2.8 (0.8)	2.6 (1.0)	n.s.
	Discuss suspicion of incorrect antibiotic treatment	3.9 (0.5)	3.6 (0.9)	n.s.
	Making suggestions is common	3.4 (0.7)	3.3 (0.8)	n.s.
	Physicians ask nurses for advice	3.1 (0.8)	3.1 (0.7)	n.s.

*Mean scores are presented per scale. All individual items were scored on a 5-point Likert scale, higher scores indicate better findings (or an improvement) on that domain.

To ensure that repeated participation (nine respondents filled out the pre- and post-implementation questionnaire) did not influence the results, we checked if the scores between repeated and single participation differed. The same direction of effects was found in all domains, except for Persuasiveness and the four ASP-behavior questions (see

additional file A). Independent samples T-tests showed a significant difference between the repeated and single participants in their baseline mean scores on Speed and the ASP item Suggestions, respectively 3.00 and 2.20, $p=.030$ (Speed) and 2.33 and 3.00, $p=.043$ (ASP item Suggestions about antibiotic treatment, see additional file A)

Scenario tests - The scenario-based tests show that with the application, nurses solve the scenarios faster; on average they need 112.6 seconds with, and 180.0 seconds without the app to reach a conclusion (see Table 3). Independent samples T-tests showed no differences in mean scores between single or repeated participants (see additional file A). The right conclusion is not reached easily: in 51% of all scenarios in the control condition and 43% of the intervention condition nurses resolved the scenario correctly (see Table 3).

Table III. Scenario-test outcomes

	Baseline	Control	Intervention
Amount of participants	16	17	16
Amount of scenarios	47	51	46
Average time needed to solve a scenario in seconds (SD)	248.5 (132.5)	180.0 (90.5)*	112.6 (78.4)*
Amount of scenario's solved correctly: code 7 (%)	16 (34%)	26 (51%)	20 (43%)

*difference between intervention and control group significant ($p=0.000$)

In all conditions, participants reach a correct answer more often than any other possible outcome; 34.0%, 51.0%, and 43.5% of all scenarios at respectively baseline, control, and intervention were resolved correctly (see Figure 4). The second most prevalent scenario outcome was performing a search and calling in for external help. The control and intervention conditions differed little with 19.6% and 21.7% of the scenarios resolved this way. During baseline, nurses were a bit more likely to involve someone after a search than in the other conditions; in 27.7% of the scenarios. In the intervention condition, more wrong answers (15.2%) and nurses giving up after trying to search (10.9%) were found than in the control or baseline condition. However, not one nurse in the intervention condition gave up immediately after reading the scenario, whereas especially in baseline (21.3%) and also in the control condition (5.9%) this did happen. Figure 4 further shows that at baseline nurses provided a correct solution based on incorrect (or invalid) information (10.6%), more often than in the control (5.9%) or intervention conditions (2.2%).

Nurses were on average faster in resolving their scenarios when using the app, especially when they did not find the correct information and gave a wrong answer, gave a right answer based on the wrong information, or used the right information to reach a right answer (respectively 83.1, 91.0 and 74.0 seconds), as Figure 5 displays. Especially during baseline, wrong answers, involvement of external help after search and right answers after wrong information was found made the search lengthy (respectively 241.0, 290.0 and 331.0 seconds).

Figure 4. Scenario solutions per condition

Figure 5. Time needed to solve per scenario outcome

Solution category 3 was not calculated, as participants instantly 'gave up', and called for help

Over all conditions, scenario 1, 2, 3, and 5, all scenarios with fairly common tasks or dilemma's (regarding dosage, preparation, and administration task instructions), were most often answered correctly (respectively 65%, 75%, 73%, and 73%), as can be seen in Figure 6. Scenario 4, 6, 7, and 9 on interaction and compatibility of drugs and renal failure triggered searches, but resulted eventually in calling in for external help (respectively 29%, 50%, 65%, and 31%). Related to this solution category are the solutions where the participant gives up after a search (and does not suggest that external help is needed),

which occurred most often in scenario 9 (resolved in 23% by giving up). Scenario 7 and 9 also triggered an immediate call for help, without searching (respectively 18% and 23%). Wrong answers were provided most often in scenario 6 (19%) on IV compatibility and scenario 8 (28%) on drug-drug interactions (Figure 6).

With the application, nurses seemed to conclude they cannot find information and give up or call in for help a bit more often than in general (see Figure 6 and 7), especially in the scenarios that were at the 'border' of nurse responsibility and expertise (scenarios 4, 6, and 7). Especially the more straightforward and very familiar tasks of checking how fast to administer something and what the standard dosage is (scenario 2 and 5), were performed well in general, and perfect with the app (Figure 7).

Figure 6. Solutions per scenario

Figure 7. Solutions per scenario with the application

Discussion

The risks that antimicrobial resistance pose need to be countered, and ASPs offer bundles of strategies contribute to limiting this problem in clinical settings. Because nurses are an often overlooked stakeholder in ASPs, we set out to support their antimicrobial-related tasks by developing an information application that incorporates PSD strategies [8]. The results of this study show that the application contributed to the overall information situation of nurses regarding aspects of perceived persuasiveness (reliability and unobtrusiveness) and usability/user satisfaction (relevance, user friendliness, speed, hyperlinks). As no new information was supplied via the app (it merely centralizes readily available information), we can confirm that the mode of offering information is an important contributor to user satisfaction. This positive user experience translates to the time nurses need to seek information to reach a conclusion in the scenario tests: nurses solved scenarios faster with the app than without it. However, the quality of the solutions they reach with and without the app is diverse and not in all cases better with the antibiotic application than without it. Paradoxically, easier access to information may improve awareness but not necessarily supports the ability to process the information, leaving nurses incapable to resolve the scenario.

The improvement of the general information situation of the nurses is in line with previous analysis of application use (steady throughout pilot period) and positive evaluations of the application regarding usability and user satisfaction [18, 22]. The application is valued positively, used steadily, and according to our results, contributes to the overall information support of the nurses. However, no concrete (self-reported) effects on communication, safety attitudes and antimicrobial stewardship behavior were observed. Possibly, the application was mainly used to perform antimicrobial-related tasks that are within the nurses' traditional domain (preparing antimicrobials for use, administering them), and less to educate or emancipate them regarding more complex tasks such as recognizing sub-optimal treatment, and alerting physicians or pharmacists in case of severe side effects, possible interactions, or other adverse effects possibly due to suboptimal treatment. This explanation is supported by an analysis of the log data of the application which shows that mainly pages with instructions for preparation and administration of antibiotics were accessed [18], hinting again towards task support as the main persuasive strategy that comes forward in this application.

Congruous with the absence of any improvement in communication, safety attitudes, and antimicrobial behaviors, the scenario based user tests show diffuse findings regarding the quality of solutions for the scenarios, even though the app did enable the nurses to reach their answer faster. However, as nurses often indicated they were unable to find or correctly process the information to be able to draw a conclusion (and thus call in external help), or they drew a wrong conclusion, it appears that more basic knowledge of

antibiotic stewardship and nurse-aimed information are necessary to be able to make correct decisions regarding antimicrobials. Acquiring this information and knowledge was not, or insufficiently, supported by the app. As addressed in other research [25], nurses must first recognize the problem and their need for information (uncertainty). Also, they need to know where to look and what type of information may be relevant in a certain case (e.g., in order to find out whether it is a 'regular' side effect that causes the problem, or a drug-drug interaction that is at play). Focusing on solid information systems alone is insufficient in such contexts [25]; when awareness and empowerment lacks and information searching does not run smoothly, nurses in our study indicate they would stop and call someone. This is in line with other research [26], illustrating a preference of nurses for human information sources regarding drug information, even though availability and being evidence based are not always ensured. Thus, to support nurses in ASP, a combination of (usable) information resources and adequate training and ready knowledge regarding antimicrobials should be in place. Especially the ready knowledge and monitoring skills in ASP ask for explicit training and application of other persuasive strategies besides better accessible information and task support; the results show that scenarios that required more than locating and carrying out concrete instructions (such as interpreting information on side effects or interactions, as opposed to preparation instructions) were most difficult to solve. The app may have increased awareness among nurses regarding the more complex tasks, causing them to quicker conclude that they are not an actor or responsible (and calling in help). In this sense, the technology does trigger awareness and uncovered a new focus for nurse education.

Nurses strongly stating that a certain scenario was irrelevant to their task domain, was an unforeseen finding in our study. However, it informs us about nurses' view on their role in ASP. Some of the scenarios were intentionally created to be at the intersection of nurse and physician responsibility in recognizing sub-optimal treatment circumstances and being able to detect possible sub-optimal treatment situations underlines the value of (often present) nurses in ASP. Often, nurses in our study instantly indicated that they played no role in the scenario that was presented to them, and were subsequently unable to retrieve the information needed or interpret it correctly. Our results show that supplying information in itself does not support the emancipation or an active role of nurses in ASP, but it does create awareness. Active learning strategies have been proposed as a necessary complementation to create ownership and increase knowledge among nurses [26] in general and in ASP [14]. In our study, we suspect that the residents in this teaching hospital, who were often present on the wards, may account to some extent for the situation where nurses can easily call in for help. Possibly, in hospitals where physicians or pharmacists are less easily accessible, nurses may be more inclined to start searching and be more persistent continuing searching until sufficient information is found, as there is no (quick) alternative.

Limitations and future research

This study may have some limitations that compromise the robustness of our results. The duration of the pilot (eight months) inevitably means that changes in the population occurred. Also, the amount of nurses working on these wards, the partially independent samples, and the questionnaire non-response have limited our ability to draw firm conclusions. However, we were able to provide a good proof-of-concept, and identify issues that need to be resolved to improve ASPs with nurse involvement, such as training. Also, we were mainly interested in overall (ward-level) effects rather than individual (within subject) effects, as we believe that in highly cooperative jobs such as nursing, where colleagues are easily asked for assistance or help, effects of an intervention on one person will probably not be limited to that person but may spread among colleagues. Following this rationale, for implementation the strategy of *link nurses* is often used, where the (trained) nurse functions as a linking hub to spread the intervention/change [27].

Aside from individual changes/effects, the overall pre-post questionnaire results may have suffered from external influences, such as visits from the Dutch healthcare inspectorate to the pilot hospital to address (among other things) medication safety [28]. These inspectorate activities could have triggered some nurse awareness on antibiotic stewardship and guideline adherence, which caused nurses to evaluate their information sources more scrutinized. Likewise, (national) media attention for AMR may have triggered increased nurse involvement and awareness over time. These external influences may have caused the nurses to apply a more critical view onto their ward, therefore not acknowledging possible (subtle) improvements in ASP behavior, but rather stressing the imperfect state of ASP behavior. Especially in the ASP-behavior items we observed great variety in the responses. Nurses thus do not agree much on the state of ASP behaviors on their ward. Lastly, this pilot study in this specific setting may suffer from generalizability issues concerning the effectiveness of information centralizing applications. However, other studies do show similar evidence [5] regarding these kinds of information integration concepts. In addition, this study does make a strong case for a tailored, human centered approach to develop information systems, although feasibility to perform this on larger scales remains a challenge [29].

In future research, the implementation of information application combined with educational activities can be carried out and studied [30], and if successful, on a larger scale and as part of an antimicrobial stewardship program. This way, besides changes in behavior, which are a prerequisite for any other observable effects, changes in antimicrobial stewardship processes (antimicrobial expenditure, resistance patterns) and quality of care (e.g., length of stay, mortality, complications) can be assessed.

Conclusion

User-friendly, task supporting information that is integrated into one application does enable nurses to perform their tasks more efficient (fast). However, empowerment of nurses in Antimicrobial Stewardship needs a more active approach and cannot rely on subtle PSD strategies such as task support and unobtrusiveness. To benefit from nurse input in ASP, they need to be made aware of their roles and responsibilities in ASP, via education or training, possibly applying social strategies as well.

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Additional file A

Table A. Questionnaire mean scores, compared for repeated/single participants

Scale	Subdomain	Pre- implementa tion repeated (n=9)	Post- implementa tion repeated (n=9)	pre-post differenc e repeated participat ion	Pre- implementa tion single (n=20)	Post- implementa tion single (n=9)	pre-post differenc e single participat ion
PPQ	Task support (2)	4.11	4.17	0,06	3,88	4,44	0,57
	Reliability (1)	4.00	4.33	0,33	3,60	4,33	0,73
	Persuasiveness (3)	3,93	3.89	-0,04	3,77	3,81	0,05
	Unobtrusiveness (4)	3.17	3.58	0,42	2,69	3,78	1,10
WEQ	Relevance (3)	3.59	4.00	0,41	3,62	4,15	0,53
	User friendliness (3)	3.00	3.30	0,30	2,78	3,33	0,55
	Speed (2)	3.00 [^]	3.50	0,50	2,20 [^]	3,89	1,69
	Hyperlinks (2)	3.56	3.94	0,39	3,30	4,06	0,76
Nurse-Physician Q	Openness (4)	3.78	3.89	0,11	3,68	3,69	0,01
	Accuracy (5)	3.64	3.71	0,07	3,31	3,47	0,16
	Understanding (8)	3.19	3.36	0,17	3,14	3,47	0,33
SAQ	Teamwork (14)	3.90	3.96	,06	3,73	3,82	0,09
ASP Behavior	Give suggestions about antibiotic treatment	2.33 [^]	2.78	0,45	3,00 [^]	2,33	-0,67
	Discuss suspicion of incorrect antibiotic treatment	3.67	3.67	0,00	3,94	3,44	-0,50
	Usualness of giving suggestions	3.22	3.33	0,11	3,44	3,22	0,22
	Physicians ask nurses for advice	3.11	3.22	0,11	3,11	3.00	0,11

[^]significant difference between single/repeated participant groups in pre-measurement (speed $p=.030$; give suggestions about antibiotic treatment $p=.043$)

Table B. Time compared for repeated/single participation

Time needed to resolve a scenario				
Condition	Repeated participant	Mean	SD	N
Baseline	yes	238.87	100.722	15
	no	255.38	153.311	21
	Total	248.50	132.503	36
Control	yes	189.38	102.917	8
	no	178.08	89.148	39
	Total	180.00	90.529	47
Intervention	yes	111.33	88.721	12
	no	113.06	75.868	34
	Total	112.61	78.395	46

Chapter 7. Persuasive elements in Log Data

This chapter is based on:

Wentzel, J., de Jong, N., Nijdam, L., van Drie-Pierik, R., & van Gemert-Pijnen, J. (2014). Understanding eHealth use from a Persuasive System Design Perspective: An Antibiotic Information Application for Nurses. *International Journal on Advances in Life Sciences*, 6, 210-219.

Abstract

To ensure optimal treatment and patient safety, nurses need easily accessible information. An application was developed to support nurses in their antibiotic-related tasks. With log data analysis and user interviews we evaluated the application. We aimed to interpret log data by applying the Persuasive Systems Design model. The results show steady, continuing use that corresponds to nurse tasks regarding timing and content of use. Task support seems a top relevant motivation for using the system, given positive user comments and most popular content of instruction pages. The results show that a combination of log data and user interviews help to understand use and uptake of an application in practice.

Introduction

In this paper, we provide a more in-depth analysis of actual use (log data), elaborating on the effects of an antibiotic information application for nurses that was presented at eTelemed 2014, the sixth International Conference on eHealth, Telemedicine and Social Medicine [1]. Managing constant information needs is among one of the many tasks of Health Care Workers (HCWs). Increasingly, integration of information and support via online or mobile applications can facilitate HCWs. This is especially the case when working in complex medical settings, or when dealing with situations that require good interpretation of information from multiple sources [2]. For good support, applications should be integrated with daily work practice. Therefore, besides studies on behavioral or clinical outcomes, understanding of application use and use context is pivotal to the development and improvement of eHealth applications for clinical settings. This paper focuses on understanding of use data as a prerequisite for interpretation of effectiveness.

Ehealth to support tasks

Information and communication technology holds the promise of facilitating information transfer and offering support in a variety of health care settings [3, 4]. Applications aimed to support health care workers (HCWs) are abundant, both in mobile applications (for smartphone or tablet), in websites, and web apps [2]. However, sometimes applications and websites that are supposed to facilitate and support HCW's jobs are perceived as distracting, user-unfriendly and ill-fitted to work practice, thereby possibly compromising patient safety [5-7]. Taking a more user- or practice- based focus throughout the design phases may help to overcome these difficulties [6, 8]. By taking this focus, user needs and implications of use context are balanced with stakeholder values and needs, to reach an optimal fit between user, organization and technology [8]. However, in professional clinical settings, conducting such user-driven formative studies can be a challenge, due to practical (time, access) and ethical considerations. Therefore, requirement elicitation strategies that take into account the specific boundaries of medical settings have been proposed [9].

Persuasive system Design

Another development approach that may facilitate implementation, uptake, and effectiveness of eHealth applications includes incorporating Persuasive Systems Design (PSD) into technology. In this model, the targeted behavior is reinforced, shaped or changed by the technology, thereby 'persuading' its users [10]. This persuasion can occur via different strategies, which depend on an analysis of the context. The system qualities should be adapted to this context, using one or more strategies: primary task support, dialogue support (facilitating interaction with the system), credibility support (credibility of the system and its content), and social support (strategies that include others, integrate the system in interpersonal interaction or comparison). The strategies are supported by

design principles that exemplify how to operationalize a certain persuasive strategy. For example, including tokens of expertise (regarding content) in the system contributes to credibility support [10].

Designing technology in such way that it is unobtrusive, useful, and easy to use helps to blend the technology seamless into users' work (or life) and to quickly reach their goals. The model is applied to the design and evaluation of health interventions aimed at (changing health behavior of) patients or non-professional [11], but the principles apply to professional-aimed eHealth tools as well [12].

Information support for antibiotic stewardship

Information support can be especially useful in areas where complex medical situations arise [13]. Clinical antibiotic use is such a situation. Mis- or over-use of antibiotics contributes to the problem of antibiotic resistance. Due to their resistance to antibiotics, infections caused by resistant pathogens are difficult to treat. Therefore, prudent use of antibiotics is needed to stop resistance forming and preserve the effectiveness of these drugs [14]. Antibiotic Stewardship Programs (ASPs) aim to optimize antibiotic use in clinical settings. Formulary restrictions, antibiotic cycling, multidisciplinary bed-side consultation and improved diagnostics are some strategies that are used to this end. Infectious disease specialists, clinical microbiologists, pharmacists and physicians work together in ASP to improve antibiotic use. Optimal antibiotic therapy relies on timely adjustment of therapy, based on lab results (diagnostics) as well as careful monitoring of patient progress and vital signs. Correct execution of antibiotic therapy (including preparation and administration of the medications) as prescribed by the physician stands at the base of successful ASPs. In addition to expert input in ASPs, nurses contribute a great deal [15]. Nurses spend a lot of time caring for and observing patients; they are the 'eyes and ears' of the physician and notice changes in patient status that call for action (e.g., antibiotic therapy adjustment).

In earlier research, we identified nurses as an important stakeholder for ASPs [16]. However, in literature and practice, physicians and clinical experts are regarded as the main actors in ASP, and nurses' roles are not made explicit [15, 17]. As earlier research indicated that nurses have high information needs regarding the antibiotic care process, we aimed to optimally support nurses in their antibiotic-related tasks. We applied Human Centered Design to develop an information application, that takes user needs into account and provides bed-side task support. With regard to nurse support in antibiotic stewardship, no dedicated applications were identified in literature, as nurses are often overlooked as stakeholder in ASPs. Nurse tasks in ASPs are demanding and ask for good information integration and decision making: nurses gather information from different information systems, integrate it, and decide whether further action is required. Previous research indicates that especially task support and system credibility strategies from the Persuasive

Systems Design model are influential; formative evaluations revealed a lack of task support and easy accessible information [16], which can be a barrier for nurse empowerment in ASP. Based on this understanding of the work context, we developed an application, the Antibiotic Information Application (AI Application).

Study aim

In this study, we aim to assess if and how the AI Application fits into nurses' workflow and nurses are motivated to use it. To this end, we analyze actual use patterns (time of use and content viewed) and combine this log data with data on user satisfaction as resulted from our qualitative evaluations.

The antibiotic information application

Based on formative evaluations, the Antibiotic Information Application (AI Application) was developed [17]. In focus groups, interviews, scenario tests and usability tests nurses in our pilot research expressed a need for an easily accessible, centralized information application, where they can find all information on antibiotics they need during their work. This includes instructions on preparation and administration, as well as background information and information that is needed on specific occasions only (e.g., when side effects occur). On the basis of the previous results, a prototype was created in WordPress [18], with some alterations to fit our specific content management demands (e.g., flexibility of button-order and features for import and export of content). Based on its evaluations (user tests, user interviews), a final release was launched. This application is web-based, and can be run from the hospital's own server. However, for the pilot study the system was made available via the internet, and was taken up in the nurses' personal hospital start page and medication administration system so that it can be accessed easily. Besides for use on a PC, the AI Application is optimized for mobile use (tablet, smartphone). For the application's content, the information sources that were already used in this hospital served as input. This included general reference works and national guidelines as well as the hospital's own protocols as created by the hospital pharmacy. All sources were 'chopped up', where needed, selecting only the content that is necessary for nurses to execute their tasks (the original sources often contain much information aimed at physicians or medical experts, which can be irrelevant and confusing to nurses). This process was done based on formative research outcomes regarding information needs, and expert views (clinical microbiologist, pharmacists) on what types of information should be available to nurses to be able to contribute to ASPs. The different types of content are ordered according to the mental models of the nurses as they resulted from the card-sort study that was conducted during formative research phases [17]. Users select an antibiotic from a drop-down menu or type the name in a search field to access an overview page (see Figure 1). On these overview pages, information is grouped by the following categories:

information needed to perform the primary tasks, warnings, general or background information, extra checks and safety information, and information for specialists and medical background (see Figure 1). Figure 2 shows an instruction page of the AI Application, showing information on drug administration, including what to pay extra attention to. A demo (in Dutch) of the AI Application can be accessed online via [19].

Figure 1. Screenshot of an overview page

A: Open search field to search an antibiotic, B: Drop-down menu to select an antibiotic, C: Open search field to search within the pages of the selected antibiotic, D: information blocks, arranged by task and/or relevance. (originally in Dutch)

Figure 2. Screenshot of a target page

A: Back-button B: print and email buttons, C: Search field, D: Breadcrumb trail, E: Instruction block on administration, F: Source with link, G: Information on last update of the information block. (originally in Dutch)

By providing easily accessible information, nurses may be better equipped to perform antibiotic related tasks. For example, it helps them to recognize and address instances of suboptimal antibiotic use. This supports improved knowledge and recognition of instances to optimize antibiotic use and nurse empowerment to discuss patient therapy and alert physicians in case of suboptimal antibiotic use.

As nurses are generally aware the importance of looking up information, it is not a lack of awareness that hinders information use. Rather, inaccessibility and incomprehensibility of information is the problem: nurses lack time and knowledge to localize and interpret the various information sources to be able to apply them quickly during their work. Therefore, in this case, persuasive strategies that focus on creating unobtrusive, easy to use information, that supports tasks are most likely to contribute to a positive user experience and effectiveness. In the AI Application, reduction and tunneling (among others) realize these strategies: the amount of actions to reach information are decreased by integrating all information in one application (reduction) and users are guided directly to the desired information via the overview grid (tunneling), as can be seen in Figure 1.

Methods

Participants

Two lung wards of a local 1000-bed teaching hospital participated in this research. The wards have a total of 57 beds. During the pilot phase, 62 nurses (45 FTE) worked at the two wards. Approximately 15 of them were informed about the AI Application and the importance of antibiotic stewardship in presentations and were encouraged to share this information with their colleagues. In addition, all nurses received an email with instructions and fact-sheets on antibiotic stewardship and the AI Application were distributed repeatedly throughout the wards.

A convenience sample (based on availability during the weeks of interviewing) of thirty-four nurses participated in the AI Application evaluation interviews. These nurses have an average age of 32 years, and 29 of them are female, 5 are male. On average, they have 9 years work experience as a nurse, and 6 years work experience on their current ward.

Log file analysis

To get more insight into the working mechanisms of the technology that is implemented, actual use of the technology can be studied. Log data analysis provide a means to study technology use in an ecological setting. The AI Application was introduced at the two pilot wards where users could access it directly on a pc. Login was performed based on IP recognition. To ensure whether the AI Application fulfills information needs, at what moment these needs arise and what information is viewed, AI Application use is logged

using Google Analytics [20], as well as a Wordpress plug-in because of additional information the two systems provide; e.g., the plug in identified users (including admin) whereas Google was able to provide overviews of most viewed content. Log information of interest includes number of visits per day, time of day with most visits, most frequently viewed content and visit duration. Also, preferred search methods, entry and exit pages are assessed. Only log data from the hospital's IP address is considered, to filter out application use by third parties (e.g., maintenance) not included in the pilot.

Intended use

To make sense of the log data for answering the research questions, the intended use of the AI Application must be defined. With regard to intended use, some remarks from our earlier research can be made. Antibiotics are administered several times a day in the wards, but nurses indicated during development phases that they especially look for instructions when dealing with antibiotics that are unfamiliar to them or when a patient reacts to the medication in an unexpected way (side effect or allergy). Also, inexperienced nurses may need to look up information more often than experienced nurses [17]. The frequency of critical moments, when an unknown antibiotic is prescribed or when an unexpected event related to an antibiotic occurs, is unknown. Because nurses share information, not every individual nurse may need to consult the AI Application every time he/she cares for a patient who receives antibiotics. Therefore, a precise estimation of intended use is hard to give but multiple visits per day (overall use) are expected.

User interviews

Semi-structured interviews with nurses (n=34) were held to assess their satisfaction with the AI Application, eight months after implementation. First, participants were asked to perform a few information seeking tasks. Half of them was asked to use the AI Application (n=17) for this, while the other half of the participants (n=17) was asked to use the regular information sources that were already available and used prior to this pilot study (pre-implementation information sources), such as traditional guidelines. The participants were asked to 'think aloud' [21] to assess overall positive or negative user experience of the AI Application as compared to the pre-implementation information sources. In addition, during these sessions short interviews were held to ask participants about their opinion of the AI Application, how satisfied they are with it, and if they would like to change anything about the application. Audio recordings were made during these individual sessions. The transcripts of the 'think aloud' data were transcribed and categorized into positive, neutral, or negative remarks. The transcripts of the interview part of the sessions were coded using the PSD model, as previous work on a sub-sample of our dataset showed that this model [22] helps to clarify the cause of (dis)satisfaction with the application. The data was analyzed using the constructs of the Perceived Persuasiveness Questionnaire [23] as a

coding scheme. This questionnaire measures perceived persuasiveness; the extent to which persuasive strategies are recognized (present) in the system by measuring to what extent users experience primary task support, dialogue support, perceived credibility, social support, unobtrusiveness, perceived persuasiveness, perceived effort, perceived effectiveness and use continuance. As not all persuasive strategies are present in the AI Application, because of the strong focus on primary task support, some constructs were adapted in our coding scheme: perceived effectiveness and primary task support were merged. Previous research showed that these constructs overlap in measuring the AI Application's perceived persuasiveness [22]. The data were analyzed by two independent coders [JW, NdJ], first to identify relevant transcript excerpts, and second to apply a certain code.

The transcript excerpts coded according to the PSD-based coding scheme are not the same excerpts that were used to establish satisfaction during use; the latter comments are the verbalizations of thoughts made while executing tasks with or without the application, while the PSD-coded comments constitute interviews transcripts.

Results

The eight month pilot period provides prolonged insight into use and user satisfaction with the AI Application.

Figure 3. Daily AI Application visits throughout the pilot period.

Log file analysis

The AI Application was launched at the end of March 2013, and has been used 5.21 (SD 3.09) times per day on average during the pilot period (April 2013 – Nov 2013). The bounce percentage is 11%; in these cases users left directly after entering. On average, visits lasted

2.5 minutes. The log files show a variable, but steady use of the AI Application over time (see Figure 3). This use pattern continues after the pilot phase (as the application continues to be available). During week days (Monday to Friday) the AI Application is used more often (14-16% of visits per week day are on one of these days) than during weekends (11% of all visits occur on a Sunday, 13% on a Saturday), as can be seen in Figure 4. When data are arranged by visits per hour of the day, peaks around 08:00h, 12:00h, 17:00h and 21:00h are visible (see Figure 5).

To access the antibiotic pages, users prefer the search field over the drop-down menu; 74% vs. 26% out of 3,060 search instances. Pages that are viewed most often, aside from the welcome page and antibiotic overview pages (see Figure 1 for an example), are pages of the category task instructions (Figure 1, section A): information on dosage, 189

Figure 4. AI Application visits per day of the week.

Figure 5. Hourly AI Application visits throughout the pilot period

Figure 6. Page views in percentage per section.

page views (8.5%), instructions on preparation, 1,025 page views (46%), and instructions on administration, 516 page views (23%). The other categories (see Fig. 1, section B-E) generate less page views, ranging from 2-84 (0-4%) for individual pages and 49-247 (2-11%) per category (see Fig. 6). Information on the antibiotics Amoxicillin-Clavulanic acid, Ceftriaxone, and Ceftazidime was viewed most often with page views (including overview pages) of respectively 717 (16%), 609 (13%), and 537 (12%).

User interviews

While using the AI Application during the interview, users commented on the ease and support they experienced when working with it. Table I show the types of remarks participants made while searching for information with the application or without it (pre-implementation sources).

Overall, more negative than positive remarks about the pre-implementation information sources were made (see Table I). The negative comments regarding the pre-implementation information sources (negatively) addressed the ease of finding information and clarity of the sources:

"I want to remark that I do not think this [table of drug-drug interactions, ed.] is good, because it is very, very small. And when you zoom in, you cannot see it precisely and that is when you make mistakes".

TABLE I. USER COMMENTS DURING SEARCH

	Pre-implementation sources		AI Application	
	Comments	%	Comments	%
Positive	18	14	97	56
Neutral	10	8	12	7
Negative	104	79	63	37

However, positive remarks on the pre-implementation sources include that information is nonetheless available and there is always a way to find it:

"Well, there is always the drug leaflet, and you can find this type of information in there. And I think it is just as fast to search for it in the leaflet [...] Takes precisely as much time [as other search methods, ed.]".

The AI Application generated more positive (56%) than negative (37%) comments (see Table I). Positive comments included remarks on functionality, looks and usefulness:

"You see all these nice blocks" and

"It is instantly clear where you can find the information".

Negative comments addressed the available content and problems finding information:

"That's stupid, I cannot find it right now" and

"Look, it does not show any results. I would want it to do that".

To be able to deduct why the AI Application generates positive and negative qualifications, interview transcripts were analysed using PSD constructs for coding. Table II depicts the results of this analysis. Overall, for nearly all categories the amount of positive comments outweigh the negative comments, except for unobtrusiveness (11 positive vs. 12 negative) and credibility (equal amount of 4 comments). By far, most remarks concerned primary task support (42.45%), indicating that this is a relevant concept in the AI Application's setup. Participants typically commented on how the information and setup of the AI

TABLE II. OVERVIEW OF USER SATISFACTION ANALYSIS

PSD construct	Comment load	Number of remarks (*)	% of total remarks per construct
Primary task support	Positive	63 (27)	42.45
	Negative	27 (15)	
Perceived persuasiveness	Positive	20 (15)	11.79
	Negative	5 (4)	
Perceived effort	Positive	20 (14)	13.21
	Negative	8 (5)	
Use Continuance	Positive	18 (14)	12.26
	Negative	8 (7)	
Unobtrusiveness	Positive	11 (6)	10.85
	Negative	12 (9)	
Credibility	Positive	4 (3)	3.77
	Negative	4 (2)	
Social Support	Positive	7 (7)	3.30
	Negative	0 (0)	
Dialogue support	Positive	5 (4)	2.36
	Negative	0 (0)	
total		212 (34)	100

*number of unique participants making remarks in this category

Application is specifically useful when performing their tasks. This quote illustrates it:

"[...] that it clearly shows: dose, preparation and administration. That is what I want to know. That's why I use the AI Application".

Some negative remarks concerning primary task support were given (see Table II) and address information that lacks or ways in which the AI Application cannot be used while performing tasks when this is wanted:

"You miss [information, ed.] in the AI Application sometimes. One time I had something; one gram that should be given per two grams. It doesn't say if the speed of the drip should be adjusted yes or no. That are sort of the puzzles you have to [solve, ed.]".

Comments concerning perceived persuasiveness were quite prevalent as well (see Table II), mostly indicating that using the AI Application is easy, nice or convenient. This seems a

more pleasurable method of searching than former information sources. These quotes underline that:

"[...] And it is very convenient that it is so easy to search. That it's much like our good old 'yellow booklet' [paper-based antibiotic information, ed.]" and "It works quite easily, yes".

However, some users encountered difficulties in using the AI Application that made them less motivated to use it:

"That it is difficult to read, so it is less interesting, because you'll soon feel like you don't understand and I would then just leave it to the physician".

Table II shows that many remarks addressed the concept of perceived effort: how easy it is to use the AI Application (e.g., time, number of actions required). Especially saving nurses the trouble of scanning large texts and extensive searching within the system typify these comments:

"Clear. Especially these distinct blocks and preparation, administration and the like. That it is clear where you can find it because especially with all the other sites they give you a long list and you have to search through the entire page".

However, some effort still has to be put into searching for information, as the negative comments indicate:

"Sometimes you have to search a bit further, but often you'll figure it out".

Use continuance indicated if nurses were inclined to (keep) using the AI Application, which was mostly positive for as far as nurses made a remark on this theme:

"I actually always use the AI Application" and "When I search something about antibiotics or something I always start with the AI Application, [to see, ed.] if it is in there".

A few users had little experience with using the AI Application, or mentioned they just did not use it as often as they could. This quote illustrates how the AI Application is not used in standard settings (where information still can be of value):

"Look, the standard stuff, we give a lot of Augmentin [an antibiotic, ed.], you really don't look up in the AI Application anymore".

Having a system right at hand that is easily accessible while performing tasks was mentioned as a positive aspect. Especially easy access to the AI Application via the medication registration system contributed to this unobtrusiveness:

"You want your information instantly. And this is useful for that. It is just nice that I can access it directly from this system [medication registration system, ed.]".

However, some down-time of the system and the desire for even more and faster ways to access the AI Application accounted for a few negative remarks on unobtrusiveness:

"[...] then it would become a bit more striking. [...] If you would just see it [the link, ed.] on top here, that would be clearer for the people that do not use it very often".

Credibility is not commented on very frequently (see Table II). Given the AI Application's location and support by the hospital, its credibility is valued positively, but some concerns were expressed with regard to a warning message that appeared when updates were overdue. These quotes illustrate it:

"[...] Information that you find on the internet is not specifically written for our hospital. This is".

Concerning the updates, users mentioned:

"So how reliable is the AI Application then? If it says [...] that it is not fully up to date?!"

The AI Application may play a role in social interactions, via social support; it can offer nurses a reference source when discussing or communicating a problem to physicians:

"Or just for your own information. [...] Because you want to be as well informed as possible when you call the physician".

The AI Application does not require a great deal of interaction, but some positive comments on the way search queries are handled by the system (a form of dialogue) are given:

"As soon as you type in 'am', that Amoxicillin and Augmentin are already suggested to you. I personally find that really convenient".

Discussion

Application use

The log file analysis and user satisfaction results show that the AI Application does support nurses during their work. AI Application use remains steady over time, and the bounce percentage is low (11%), indicating that most users do not leave after entering the home page but actually navigate through the site to content pages. Therefore, we conclude that the uptake is good. As the pre-implementation information sources remained available to the nurses, they had the option of not changing their primary source of information, but our data shows continuing use of the application, indicating a preference among the nurses of the wards to use it over conventional materials, months after its release.

A first possible contributor to the AI Application's uptake, is its successful introduction. To introduce the AI Application, relatively few activities were undertaken; some nurses attended an instructional meeting and fact sheets on antibiotic stewardship and the AI Application were distributed. This minimal introduction may have sufficed because the intended users initially proclaimed they liked the concept and look and feel of the application, which has possibly led to increased willingness to start using it, and spread

the word. In addition, the AI Application probably fits in with nurses' work routines as it is available via the system that nurses are already using when dealing with antibiotics, and it is easier to find than the scattered information sources they previously used. A third reason for AI Application uptake may lie in the Human Centered Design process, as involvement in the development can generate user commitment. It can be more difficult to reach this type of involvement on a large scale however.

Log data contributes to eHealth evaluation by giving insight into actual use (and uptake) [24]. However, to make sense of the log data, in terms of how the AI Application is used in daily care practice, having some concept of what intended use (how users should use the technology) should be present. For eHealth interventions in general, this usually relies on the program's setup (e.g., weekly modules require at least on log-in per week) [25]. However, for information applications that meet occasional information needs, it is difficult to determine whether users use it as intended. In the current study, we found that overall, AI Application use peaked on four moments per day; 08.00h, 12.00h, 17.00h, and 21.00h. These hours correspond roughly with medication rounds; typically nursing activities where information on preparation and administration of antibiotics is needed. In addition, in the (late) afternoon and evening there is no support from the hospital pharmacy available, which might motivate nurses to check the application in case of questions. AI Application use was slightly higher during week days than on Saturdays and Sundays. An explanation may be that usually few patients are admitted during weekends, so few new medication regimes are started, which causes a lower information need on these days. These results suggest that the AI Application is integrated in the care process as the most popular moments of use correspond to the timing of care activities involving antibiotics.

The most popular pages of the AI Application are instructions on preparation and administration of antibiotics and the antibiotics that are viewed most often are used frequently on these wards. As nurses are required to follow the instructions for preparation closely, these findings are not surprising: preparation and administration of the commonly used antibiotics are tasks that occur often. Based on the log data, the AI Application seems to primarily provide support via the procedural information [26]: instructions on how to perform certain tasks. In contrast, side effects or unexpected progress or deterioration in patient status occur less frequent, and the information that offers the background knowledge and explanations (e.g., working mechanisms, side effects), is not used as often as the concrete instructions. However, to optimally benefit from nurses' monitoring and alerting roles in ASP, having sufficient (background) knowledge that enables recognition of critical moments in antibiotic care, is needed too. The log data suggest that a more interactive learning method for information that supports this behavior is needed, as background information is used less often. In this sense, primary task support is a useful persuasive strategy to fine-tune information to support workflow. For learning new

behaviors or creating awareness, it needs to be complemented with interactive learning strategies, as are applied in other persuasive behavior change systems, for example [11].

User satisfaction

The user interviews indicated that overall, nurses are satisfied with the AI Application. In contrast, the pre-implementation sources generated more negative comments. One of the possible explanations for this finding lies in the fact that the AI Application indeed greatly facilitates information-finding as compared to the sources that were available pre-implementation. This is underpinned by other preliminary research findings of our study that are currently analyzed more in-depth: a pre-post implementation questionnaire reveals that nurses judge the pre-implementation information situation worse than post-implementation situation [1].

The AI Application's clear setup that enables nurses to find information fast contributes to the positive evaluations. As was to be expected, especially primary task support as a persuasive strategy seemed relevant. For nurses, using an information system is not so much a matter of wanting to change some type of behavior, or reaching a long term goal (e.g., lose weight, increase physical activity, become less depressed), but concerns solving an instant information need. In this context, task support, for example via tunneling, contributes most. This finding is supported by the log data, which show that the AI Application is used most often when concrete tasks of preparing and administering antibiotics are performed. However, good task support possibly does not explain application use and positive appreciation entirely: we found that perceived persuasiveness, operationalized as pleasantness of using the application, was also present in users' comments on why they use the AI Application. Thus, an application can be efficient and clear, but positive user experience contributes to use and implementation as well. In addition, possibly related to this finding, unobtrusiveness and effort also contributed to, and may overlap with task support. Surely, if it costs little effort, and is not very obtrusive to use a system, users may use it more frequently thereby feeling more supported. The interrelatedness of these Perceived Persuasiveness constructs seems logical and is being studied [11, 12]. The negative remarks that were made stipulate the importance of managing information applications properly: credibility is hampered when information is not up to date and when the application cannot be accessed easily, as was the case temporarily during the pilot, users may use it less often. Users also commented on information that they wished to access via the AI Application, but was not present. This included certain types of instructions that would make their tasks easier. Also, requests for an expansion of the scope of the application to all types of medications instead of antibiotics only. This also asks for application management: either comply with the users' wishes and provide the extra information and broaden the scope, or manage users' expectations. However, besides these requests for improvement, users seem to experience

more advantages than disadvantages in using the AI Application, given the steady use and greater amount of positive than negative remarks.

Combining the quantitative log data analysis with qualitative user satisfaction interviews strengthens our understanding of the application's use: task supporting content is used most often, and is also most prevalent in our user comments. Also on other levels, log data support user comments and vice versa, thereby strengthening our view on application use and appreciation. Combining log data analysis with other methods is therefore recommendable to gain insight into why an (online) intervention is used (or not), as stated by others [24].

Considerations for implementation

Nurses spend much time and effort gathering information, so surely an application that centralizes information has much to offer. However, this implies that somehow the information from different sources needs to be centralized and the ability to do this automatically depends heavily on the type of information sources that need to be centralized. In our case, 'filling' the AI Application and managing its content was done manually because automatizing this process would be too complex and costly in this pilot phase. Individual hospitals and sometimes even individual wards use different information systems (thus, many different types of information sources to centralize), so a one fits all solution may be difficult to achieve. For long term implementation and sustainment this is an issue that must be resolved, for example by assigning quality staff or specialized nurses to keep information up to date. Expanding the application's scope to all types of medication should be taken into account too, as users explicitly requested this and problems with antibiotic information finding during formative research applied to these other types of medications as well.

With regard to implementation throughout the hospital, nurses outside our pilot ward found the AI Application on the intranet of the hospital and wanted to use it. In this sense, the application implemented itself just by being available and easily accessible. In addition, physicians to whom the AI Application was demonstrated expressed interest in a physician-aimed version. These findings show that implementation success depends on the operationalization of early design phases when user needs and context are studied, and meeting these needs within the boundaries of clinical settings. In this case, the mismatch of expert-driven content and user needs that was resolved with the application facilitated initial implementation. We tailored the various expert-based sources to fit clinical practice, something that is not done often because it costs time, effort, and multidisciplinary cooperation and understanding. In this sense, human-centered design can help to meet end-user needs [27]. However, when these needs require highly tailored information via applications with dynamic content that requires frequent quality checks and updates, this

poses some challenges. Design teams should then find a balance between available sources to manage the information, and generalizability and up-scaling possibilities.

Antibiotic Stewardship

The motive for creating the AI Application was to empower nurses so that they can make a contribution to antibiotic stewardship programs (aimed at more prudent use of antibiotics). Even though this study's results suggest the AI Application supports nurses' antibiotic related tasks, the extent to which it contributes to antibiotic stewardship remains unclear. To detect the effects of the AI Application on work processes regarding antibiotic stewardship is difficult. As nurses are not the actual prescribers of antibiotics, the effect of more knowledge and empowerment can indirectly influence actual antibiotic use. Surely, executing preparation and administrating tasks correctly contributes to prudent antibiotic use. This study shows that task support is a relevant persuasive strategy to reach this goal. Nonetheless, the log data indicate that information on side effects, acute responses, interactions and appropriate dosage is not used often. To benefit from the monitoring, recognizing and alerting role nurses can fulfill as 'eyes and ears' of the physician, we expected these types of information to be important for nurses. However, this type of information is not accessed often, possibly because critical moments occur scarcely. Another explanation can be that nurses are unaware that they can play an important role in recognizing the critical moments and/or lack time or motivation to pay attention to this. We found some evidence for this hypothesis in our formative study and preliminary analyses of app efficiency [1, 17]. Thus, it appears the AI Application offers more information that nurses actually wish to utilize during their work, but there are no indications that this overload hampers usability and applicability. In addition, instead of information support, awareness and (e)learning may be more a more relevant approach to activate knowledge in the currently less popular information categories of the application. This view is supported by a study that showed that more active learning methods did result in increased awareness and knowledge of nurses regarding ASP [28]. In addition, the ASP-related nurse tasks possibly ask for a change in safety, cooperation and communication culture, which likely is influenced by communication tools or socially-aimed strategies [29]. Possibly, persuasive strategies such as social support might be more appropriate in these situations [10].

Limitations

The outcomes of this research must be interpreted with appropriate caution because of several possible limitations. First of all, the AI Application was developed and tested with the help of nurses of two wards in one teaching hospital. Generalizing the results greatly depends on the specific information sources in place and the AI Application's effectiveness may differ in other settings. This is to some extent a consequence of the design approach

of zooming in in local needs and local contexts. Agile methods can be used for re-design in other wards or institutes. In this case, identification of local information sources and integrating them in the AI Application are among such up-scaling activities.

With regard to the log data it must be remarked that in the current use and log setup, no individual user can be identified. Therefore, some ambiguity remains with regard to the actual amount of users that use the AI Application. Possibly, a few nurses of the pilot wards use the AI Application often, or, a lot of nurses use it occasionally. Our interview data tells us that in our sample, the majority of respondents claim to use the AI Application whenever they need to look up information on antibiotics. How often this occurred, was very hard to assess by asking respondents. Using a personal login helps to overcome this user identity issue. However, we applied an IP-based login because this does enable easy (unobtrusive) access, which is of paramount importance for information accessibility. Furthermore, sharing logins can pose validity threats regarding correct identification of user identity, especially when multiple users use the same computer. The consequence of our approach is that outcomes can be interpreted on a population (ward) base, but not on an individual level. Still, the data are meaningful, because of the communicative nature of nursing: asking a colleague who is standing next to you is often the fastest way of resolving an information need, as other studies also demonstrate [30]. Therefore, information availability improves the information situation of an entire ward, even if not all individual nurses access the AI Application.

Another important consideration when interpreting the results lies in the pilot-ward setup of this research. Even though not all nurses were fully aware of ongoing evaluation of AI Application use during the pilot period, satisfaction measurements via user comments could have been slightly more positive because of nurses' positive attitude towards (participating in) the pilot and research instead of the AI Application. To identify and limit these types of biases, combining multiple methods to measure and correctly interpret use are crucial [24]. As we found that our user remarks correspond with prolonged AI Application use, we think this possible bias is negligible.

Future Work

Additional measurements are currently being analyzed and include scenario-based tests during which nurses are asked to resolve scenarios by searching for information with or without the app, to measure actual information seeking efficiency. Outcomes of these tests include time needed to search, number of encountered problems during search, and number of times a scenarios was resolved correctly. In addition, questionnaires to measure satisfaction pre- and post-implementation change regarding information seeking and applying information will be analyzed [1].

The AI Application will be introduced on different wards and in other hospitals, following a re-design or adaptation of the application and its content to fit local work

methods. This broad implementation will be accompanied by evaluations regarding stakeholder needs, use context and user satisfaction, following the CeHRes roadmap [8].

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Chapter 8. General Discussion

Discussion

This thesis describes how the CeHRes roadmap was applied to develop eHealth technology that contributes to safe patient care, targeting antimicrobial use and infection control. The cross-border dynamics of the care processes involved in antimicrobial use and infection control ask for a precise fit between human, technology and clinical context.

This chapter, the general discussion, starts with an overview of the main findings and lessons learned in each of the studies of this thesis. Hereafter, based on the main findings, answers to the research questions are provided. Thereafter, strengths and limitations are discussed, as well as implications for further research. This chapter ends with an overall conclusion.

Main findings per chapter

The evaluation of MRSA-net (Chapter 2) shows us the importance of involvement of users via human-centered design, because it enables the translation of expert-based guidelines into a user-oriented system [1]. Frequent and constant MRSA-net use shows that it fulfills an information need, but full integration into clinical practice may not be complete, as most website visits are short (one page) and originate from a Google search. These short visits indicate a successful translation of protocols into user-friendly technology. It demonstrates the excellent communicative potential (quick information support) that should, and can be exploited by applying human-centered design methods.

The card-sort methodology used to arrive at the MRSA-net design rendered durable results (chapter 3). The evaluation shows that this method can be applied to create long-lasting designs that match users' mental models and provides insight into (changing) information needs when real-life use (search) data is used as input [2]. Thus, the method is useful for contextual inquiry as well, because user remarks provide important additional information. Such information is indispensable for creating user-driven technology that matches user tasks and mental models, based on expert-driven content.

Not much attention is paid to clinical guideline implementation in scientific literature, as the review in chapter 4 shows [3]. Articles that do describe how guidelines were implemented show that mostly, audit and feedback, reminders, and educational meetings were applied. A better understanding of guideline implementation and effective strategies starts with more insight into who the involved stakeholders are, and the relation between implementation strategy, adherence, and clinical (or organizational) outcomes.

The development process (contextual inquiry, value specification, and design) described in chapter 5 led to the identification of stakeholders and a target group that is usually overlooked or involved minimally in guideline development regarding antimicrobial stewardship [4]. In addition, insight into tasks and communication within this care process was gained. Based on this study, the antibiotic information application was developed with the aim to serve the most urgent information needs of nurses. The methods used did not

only render input on requirements for content, design, and supporting service, but also triggered a discussion on work practices and task perception. This approach contributed to gain insight into the necessary infrastructure (fit between human, organization, and technology) for communication [5].

The summative evaluation of the antibiotic app (chapter 6) shows the added value of the used approach: understanding of context and values translated into users having a positive use experience and improved information search efficiency [6].

An analysis of actual application use (log data and user remarks during use) indicate that task support is the main strategy in this application which accounts for its uptake in clinical practice (see chapter 7) [7]. Exploration and operationalization of other persuasive elements is needed to research whether the application can further empower and support behavior that is not (yet) part of daily routine.

Requirements for an information application

The first research question addresses the practical questions of what information should be given, how the application should work, and what it should look like, to support patient safety. First, the studies on MRSA-net in chapter 2 and 3 indicate that eHealth needs to be integrated seamlessly into work practice, and it should have relevant and comprehensible content. The studies we performed to gain insight into the requirements that are needed to reach good integration, resulted in insight into the context and values that drive the need for a solution. Having relevant and easily accessible information resources were identified as the underlying drivers of the need for improvement (chapter 5). With the identification of requirements regarding content, system and service, conflicting stakes (needs, wishes, preferences, and potential) became apparent.

The relevance of user-friendly 'translations' of protocol information for healthcare workers was already demonstrated in the previous project this thesis builds upon [8]. In addition, issues regarding sustainability, maintenance, resources, and other organizational concerns are the focus of parallel studies [9]. Therefore, in weighing requirements focus was put on those requirements that enable a match with clinical practice and improvements in accessibility of information. The antibiotic app that resulted from this process aims to meet the core values by providing overview and integration of information. Because of the constant 'weighing' of conflicting requirements and the iterative character of this process (sometimes further study into the context is needed, before a decision on design can be made), keeping overview is important. By creating an overview of requirements and their underpinning, communication within the development team (researchers, programmers, designers) was supported. This requirement strategy [10], provided a structured approach that is especially helpful because much (most) of the data is qualitative, and rich of information, but without (easy) cut-off points to base decisions on.

Considerations for implementation

By following the CeHRes roadmap, we aim to answer research question 2; what preconditions for implementation should be in place? The literature study shows that a medical perspective is often applied to guideline implementation: a focus is placed on the cure and its effects, and minimal attention is given to the way guidelines are operationalized and how behavior in clinical practice is changed (chapter 4). Usually, education, audit, and feedback rounds are the core strategy of guideline implementation. It also appears that especially implementation of guidelines that affect behavior which depends strongly on the situation, receive the most attention in literature: interventions targeting hand hygiene prevailed in the review. Hand hygiene is of key importance for infection control, but at the same time adherence to correct hand hygiene practices is low [11]. Knowledge and awareness may be tackled, but evidence for its effectiveness remains scarce [3, 12]. More likely, personal or situational factors, that are difficultly changed by education, cause health care workers (and patients) to not follow guidelines [13]. Therefore, a holistic focus on the context is needed to uncover the reasons for (possible) non-adherence when implementing guidelines or other changes in care practice.

The contextual inquiry, value specification, and design phase of the antibiotic app (chapter 5) led to the identification of important issues for implementation and uptake. For example, already during formative stages, lacks in knowledge and awareness among nurses were identified, and educational activities that were organized to support implementation were created to address these issues. In addition, conflicting interests of stakeholders which affect implementation were identified during these phases. This includes deciding on who should maintain the application, and how rollout is planned. For example, nurses from other wards (not included in the pilot) started accessing the application even though they were not explicitly made aware of it. Thus, implementation occurred in a sort of snowballing fashion, also resulting in requests of users for additional content (e.g., information on other types of drugs besides antibiotics). Likewise, resident physicians expressed an interest in a physician-aimed application after seeing the nurse-aimed app. These unforeseen developments after introducing the application forces weighing of resources (time, money, technical boundaries) to accommodate the newly emerged needs.

Human-centered design to support patient safety

The third research question focuses on the contribution of human-centered design to technology that supports patient safety. This strategy, to develop persuasive technology that fits user context and needs [14], has demonstrated its value in other clinical and home-care settings [15, 16]. It does also stress the need to apply a stakeholder perspective to the various research phases, thereby not forgetting the broader (organizational or contextual) picture for which a solution (by means of technology) should be created. Can end-users be

expected to oversee what their needs are and how it will affect their daily practice? Including human-centered design methods such as scenario-based tests with (working) prototypes likely increases the chance of gaining insight into this, but a combination of user- and stakeholder involvement has additional benefits.

Our evaluations of MRSA-net (chapter 2) showed how actual use context differed from intended use (e.g., given the preferred access route). This was unforeseen, because the intended use was based on intensive studying and involvement of end-users. In addition, we found that when end-users rely on or have to adhere to guidelines that are set by experts (e.g., infectious disease specialists and clinical microbiologists), as is often the case in healthcare, conflicts may arise. Taking a human-centered approach is necessary and benefits from a discussion or weighing of user and stakeholder needs. Not in the least because user wishes come at a (financial) cost, for which users are often not the ones to pay in healthcare [17]. Chapter 6 shows that by placing the user central and involving stakeholders, improvements in user experience and efficiency can be made. This technology development approach (inevitably) opens up discussions on various fronts (task perception, technology sustainability) that should not be overlooked but welcomed as a valuable opportunity to improve healthcare. The approach uncovers processes in healthcare practice that are not easily captured in guidelines because they emerge from a combination of situational and personal factors such as the healthcare worker's experience and interpretation of the situation [18].

Human- and stakeholder-centered methods

How the focus on users and stakeholders can be operationalized in research is addressed in research question 4: How can the CeHRes Roadmap's methodologies enable the detection and application of user- and stakeholder needs and preferences? In this thesis, (mostly) qualitative research methods are used to identify and operationalize the values, attributes and requirements for technology. Even though quantitative measures can be important to depict the magnitude or urgency of a problem, we found that qualitative data has proven to be useful in identifying requirements. By using a structured approach to requirement identification, a rich and insightful variety of requirements can be retrieved [10]. The contextual inquiry is an especially important phase, because an inadequate perception of the context can lead to a (partial) mismatch and limits full uptake. To ensure stakeholder engagement in the project and mutual understanding, one can perform a multi-stakeholder focus group (or workshop), as we started out the application development process with (chapter 5) [4]. Even though group dynamics can be unpredictable and may prevent all participants from fully expressing themselves [19], observing the dynamics within the group responding to a certain issue or question renders important (implicit) information on what to be attentive to throughout the development. It can uncover target group's tacit knowledge, and situational considerations that play a

role in clinical practice but are not explicitly addressed in guidelines. Also, for the formulation of values (e.g., what is really important and why, what drives the views and wishes of stakeholders), an interactive research method such as focus groups is needed. This way, stakeholders are informed (or might even agree upon) the core goals that should be accomplished. Besides explorative or observational methods (such as desk research), a stakeholder meeting or workshop seems like a sound research activity to undertake during the early contextual inquiry [20].

Another method that contributes to the contextual inquiry is card sorting. The application (chapter 2) and evaluation (chapter 3) of the card-sort method demonstrate that a human-centered method such as card sorting renders important insight for the navigation and information structure, as well as for the context [1, 2]. The mental models and shifts in information need resulting from the card sort studies point toward important implications for content requirements and context of use. This marks a shift from rule-based protocols to practical instructions and fit with tasks.

In addition, the card-sort study that was performed during for the design of the antibiotic information application (chapter 5), showed the added value of sorting paper-based (printed) cards versus doing an online card-sort study. In a face-to-face setting, users sorting cards were triggered by the content on the cards to discuss nurse task perception. This rendered qualitative data that was used in clinical lessons to introduce the application, thus also supporting implementation. In addition, some participants chose to sort the cards into two categories (relevant vs. not relevant), which rendered important contextual insight, while these groups were of limited use for the design of the technology. In the face-to-face setting, the researcher was able to invite them to re-sort the cards, applying a different focus. Thus, this method offers design- and contextual information in a pleasurable, easy, and elegant fashion, and it involves clinical context in task instructions which is a precondition for uptake and success.

For summative evaluation (efficiency, user friendliness), we performed scenario-based tests (chapter 6), in a natural setting (at the nurses' own ward) [6]. The user tests during formative research were also done by means of scenario's (chapter 5), aimed at discovering points for improvement of the design. These scenario's reflected an expert-based view on nurse tasks in antimicrobial stewardship, which again resulted in some conflict during formative and summative research activities. More specific, nurses questioned their responsibility and role in some of the scenarios and objected to completing them (e.g., noticing a patient has renal insufficiency and checking whether medication dosage is and should be adjusted). We aimed to overcome this task ambiguity by addressing the monitoring and alerting potential of nurses in clinical lessons during the introductory period of the app. In addition, the required information was easily accessible to the nurses, which we hypothesized would minimize the objections after implementation of the application. However, the objections persisted during summative scenario-based

tests. So, when introducing new behaviors or tasks that are not originally part of the professional's (or person's) usual routine, the user's response to the scenario tasks is especially important. Consequently, the outcomes of this method stress the iterative nature of the CeHRes roadmap. They demonstrate how that scenario-tests during the design phase can uncover ambiguity regarding tasks, which forces additional research into the context and values.

Gains in efficient technology

After the efforts put into contextual inquiry, value specification, design and implementation, evaluation of the efficiency of the technology is important and can render input for re-design [21]. Research question 5, addresses the question to what extent the approach described in this thesis leads to efficient eHealth technology. Chapter 6 and 7 show that it has resulted in gains in efficiency and seamless adoption into clinical practice, but limited support of the more complex behaviors. Especially behaviors that were not yet fully integrated into nurses' task perception were not supported optimally. Methodological issues (pilot size, sensitivity of measurements to show change) could be at play, as well as the task ambiguity that was mentioned in previous paragraphs. In out-of-lab settings, and especially in clinical settings where time to participate in research is limited and ethical considerations are at play, we need to combine methodologies to open the black box and make sense of the (lack of) results we measure [22]. One outcome measure that provides an (important) first step in explaining a lack of effectiveness and efficiency and should be measured more often is user experience, including perceived persuasiveness and usability. Touching upon these constructs (e.g., providing a more positive user experience and providing good usability) seems like a prerequisite for a positive influence of technology, and persistent use. Likewise, various factors contribute to uptake and adherence [23]. In order to understand technology effects, insight into user experience and actual use is needed [24]. Based on log data analysis, we identified task support as a most relevant persuasive strategy that is present in the application (chapter 7). This does enable better (faster) finding and application of information that supports ready known tasks and support decision making within these. However, it does not nudge users into educating and emancipating themselves regarding information that is outside their regular work repertoire. Our findings demonstrate the need to (re-)think through the rationale for choosing and operationalizing a certain persuasive strategy. For example, when the aim is to change behavior into new behaviors or to breach familiar tasks that call for intuitive decisions instead of carrying out straightforward instructions, this requires an approach that includes eLearning and social strategies. Our findings show that, as was to be expected, behaviors that are already common to a person but are cumbersome to carry out (e.g., because it is difficult, costs time), do benefit from primary task support strategies. Whether it is actually necessary for users to be aware of the strategy that is applied (e.g.,

do they perceive social support via the technology) and how to assess this, is an important topic for further study. In order to define a good strategy, again, the basis is an understanding of the context and keeping values central to identify the boundaries within which development can take place. Within these boundaries, technology offers a multitude of opportunities and strategies that can be applied with rationale.

Strengths and limitations

Within the limits that exist given the research settings and boundaries in (for example) time, a well-researched proof-of-concept is described in this thesis. Further streamlining of business models to support the resulting technologies and providing an approach for (cross-border) rollout of the technology into other wards, institutions, and countries would complement this work. The present thesis has underlined how technology development (with stakeholders) uncovers working processes and cultural and organizational structures that influence the technology's uptake, but are not manipulated easily. For example, we identified several organizational issues (e.g., maintenance, sustainability) that are relevant for implementation, but, given the focus of this research, placed issues of accessibility and user experience before them. This does prevent us from drawing profound conclusions regarding up-scaling and applicability to other clinical settings, but first explorations show promising results and opportunity for applying the present insights [25]. In addition, the research uncovered how technology can be a means to reach a goal, because the development process helps to create the infrastructure needed for information support and behavior change.

One of the strengths of our research was the ability to demonstrate how the usefulness of 'picking the low-hanging fruits' is still overlooked in nurse information supply, and how applying a human-centered focus can make all the difference in user experience. Providing good overview and usability is an important first step to facilitate implementation [26, 27]. We demonstrated how human-centered design (and relatively pleasurable to apply) methodologies (e.g., card sorting, scenario-based tests) offer valuable insights that can improve the information situation of nurses. The application of all CeHRes roadmap phases, made apparent that many methods not only result in knowledge relevant for the specific roadmap phase in which they are applied (e.g., card-sort to inspire the design), but render information relevant for other phases as well [2]. This underlines the iterative character of the roadmap. To assist this back-and-forth focus and to keep overview of core needs, values and requirements, we formulated an approach for requirement elicitation [10]. This approach guide the process of translating data from contextual inquiry and value specification into requirements for design, in such way that conflicting requirements can be weighed, and communicated efficiently with members of the design team.

Implications for research and practice

Technology development is never finished, and throughout the process new insights emerge. The CeHRes roadmap helps to recognize this and offers guidance by proposing tools and methods that support keeping an overview on different (opposing) needs, values, and requirements [20]. Further exploration of the integration of such tools into one project/study is called for, as this thesis does not fully cover all roadmap activities (e.g., no mayor focus on business modeling).

In addition, we experienced that by involving stakeholders (from all levels/backgrounds), conflicting requirements can emerge. Prioritizing them was done in a pragmatic fashion in this study, driven by the overall values (on which the stakeholders did agree), but this can also be done using other methods [9, 10], such as analytic hierarchy process [28] or methods that focus on value propositions [20]. Essential in this approach stakeholder involvement in defining values, instead of merely ranking them. Perspectives on the added value of such methods for the development of information tools for clinical settings are needed, as well as insight into assigning more or less weight to input from certain stakeholders over others.

Another research thread which surfaces from our studies is the selection of persuasive strategies to support behavior change. This thesis shows that task support and improvements in unobtrusiveness were insufficient to force uptake of new tasks. The possibilities for applying and specifying strategies of the PSD model is under evaluation in various studies, e.g., [29]. Possibly, certain strategies work best when aiming at reinforcing behavior (such as strategies for task support, or unobtrusiveness), whereas others are better fit to initiate new behaviors and attitude (such as social strategies, or strategies for dialogue support) [30]. Especially direct routes of persuasion are said to sort more effect to change attitudes [31], than the peripheral route such as the task support we provided in the antibiotic application. Thus, addressing the need and reasons for changing certain work routines or task perceptions should be included in the persuasive strategy. In early development phases, agile prototyping (with or without working prototypes) may help to assess what design strategy works best. Also, the application of psychological factors (e.g., attitude) to predict the effect a persuasive strategy has on users should be explored further [32]. In addition, cross-border (cross-cultural and cross-disciplinary) differences in preferences form an important relevant subject of study.

Our systematic review (chapter 4) shows that little attention is paid to the implementation of clinical guidelines, which prohibits us to learn from others' best practices (or failures). A recent update of this review [33] shows little has changed during recent years (this update included publications from 2010 to 2014, although there are more publications that do describe implementation in the last two years than the five years before (38 versus 29 publications). In addition, more articles describe changes made to the physical structure, facilities, and equipment (19 studies in the update versus 8 in the initial

review). So, more attention is brought to the design of physical surroundings to support healthcare worker behavior in protocol adherence. In the same manner, such attention should be paid to digital information sources and decision aids as well. Thus, we argue that practical issues regarding implementation in guideline effectiveness studies are needed, even though findings regarding adherence and uptake of guidelines are usually not the main findings of interest for clinicians. Opening this black box via studies that describe and assess the effectiveness of the implementation strategies studies such as some of the publications in our review, are needed urgently [34-37].

Conclusion

This thesis has shown that technology has the ability to support safe healthcare and decision making in clinical context. However, the influence of technology is subtle and affected by contextual issues. Especially in infection control settings, this context is complex, multi-disciplinary, and comes with some boundaries regarding healthcare worker's time and flexibility to partake in development. Finding the 'perfect' mix of influencers (persuasive strategies) is an iterative process that requires continuous checking of assumptions and weighing options and stakeholder needs. Our studies contribute to identifying this mix, with promising results, especially regarding the gains in efficiency that were demonstrated. A great potential of the CeHRes roadmap lies in its flexible application of methodologies throughout development phases (e.g., design outcomes can inspire renewed contextual inquiry) and a focus on bottom-up and top-down approaches. Such an approach has the potential to innovate care, not solely by coming up with technology, but by breaking open a discussion about values, care, tasks, and creating awareness.

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Samenvatting

eHealth technologie, informatie en communicatietechnologie die gericht is op het bevorderen van gezondheid, biedt naast technologie die door burgers, patienten en zorgverleners kan worden gebruikt om informatie te verkrijgen of uit te wisselen, ook een mogelijkheid tot innovatie en emancipatie van haar gebruikers. Een belangrijke voorwaarde om te kunnen profiteren van deze mogelijkheden, is dat de technologie bruikbaar en goed inpasbaar moet zijn in de werkwijzen, en aansluit bij de wensen en vaardigheden van de doelgroep. Het verkrijgen van een goede aansluiting tussen mens, technologie en organisatie of context begint in de vroege fasen van de ontwikkeling van de technologie. Een strategie om zo'n aansluiting te verkrijgen, is human-centered design; een ontwerpstrategie waarbij de mens (eindgebruiker) tijdens het ontwerpproces centraal wordt gesteld. Omdat de mens doorgaans niet in een vacuum leeft en gebruik maakt van technologie, is het belangrijk ook oog op de context te houden, en de waarden (en voorwaarden) van relevante stakeholders mee te nemen tijdens het ontwikkelproces. Het Center for eHealth and wellbeing Research, CeHRes¹, biedt een Roadmap waarmee gebruikers en andere relevante stakeholders in het ontwikkelproces van eHealth-technologie kunnen worden betrokken.

In dit proefschrift is het ontwikkelproces van eHealth-technologieën bestudeerd, aan de hand van de ontwikkeling van een antibiotica-applicatie voor verpleegkundigen, die deel uitmaakt van het platform Infection Manager². Het onderzoek is deel van het grensoverschrijdende project EurSafety-Health-Net³, workpackage 2.2 ('verdere ontwikkeling van een kwaliteitsnetwerk EurQHealth en kwaliteitscontrole'), 3.1 ('burden of disease' en gezondheidseconomie), 3.2 ('eHealth, structuren voor bijscholing en training'), en 4.7 ('telematiekplatform, communicatieserver, internetpresentie, publiciteit').

De deelstudies zijn uitgevoerd in de context van grensoverschrijdende zorg. Dit is van belang vanwege de toenemende risico's op zorggerelateerde infecties die zich voordoen bij de zorggerelateerde migratiestromen. De toename van pathogenen die resistent zijn voor een of meerdere typen antibiotica vraagt om een grensoverschrijdende en grondige aanpak. Een van de aandachtsgebieden binnen het EurSafety-Health-Net project is verantwoord antibioticagebruik. Door antibiotica alleen in te zetten op de momenten wanneer dat écht nodig is - gepast gedoseerd en op de juiste manier toegediend - kunnen negatieve consequenties die geassocieerd worden met het inzetten van deze medicijnen (zoals resistentievorming) beperkt worden. In de deelstudies is onderzocht hoe het proces van antibioticagebruik en de daarbij behorende samenwerking over lands-, instellings- en discipline grenzen heen kan worden ondersteund door eHealth. Daartoe is gebruikersgestuurd onderzoek uitgevoerd, volgens de CeHRes roadmap. In de verschillende studies wordt duidelijk dat een socio-technische aanpak nodig is; de

relevante zorgprocessen zijn multidisciplinair, de informatiebehoeften divers, en de informatiebehoefte en – uitwisseling strekt zich uit over afdelingen, beroepen, instituten, regio's en landen.

De hoofdvraag van dit onderzoek is: *Hoe kan technologie ingezet worden om informatieondersteuning voor veilige zorg en klinische besluitvorming te realiseren, met behulp van de CeHRes Roadmap?* Deze hoofdvraag is verder uitgewerkt aan de hand van de deelvragen:

- 1) *Welke inhoud, welke functionaliteit en welk ontwerp is nodig?* (hoofdstuk 2,3,5)
- 2) *Aan welke voorwaarden voor implementatie moet worden voldaan?* (hoofdstuk 4, 5)
- 3) *Welke bijdrage levert human-centered design aan het bevorderen van veilige patiëntenzorg via technologie?* (hoofdstuk 2, 6)
- 4) *Hoe leiden de methodieken uit de CeHRes Roadmap tot het detecteren en uitwerken van de behoeften en voorkeuren van gebruikers en andere stakeholders?* (hoofdstuk 2,3,5,6)
- 5) *In hoeverre leidt de beschreven aanpak tot efficiënte eHealth-technologie?* (hoofdstuk 6,7)

De aanleiding voor de studies is het voorgaande project MRSA-net, waarin bestrijding van de Methicillin Resistente Staphylococcus Aureus (MRSA) centraal stond. De activiteiten in dit project leidden tot de ontwikkeling van de protocollen website www.MRSA-net.nl. In hoofdstuk twee beschrijven we de ontwikkeling en evaluatie van de deze website, waarbij human-centered design (HCD) principes zijn toegepast en bestudeerd. Hieruit kwam naar voren dat het centraal stellen van de eindgebruikers (zowel zorgverleners als patiënten) belangrijke inzichten oplevert voor de wijze waarop eHealth-technologie moet worden ontworpen, zodat het aansluit bij de belevingswereld en mentale modellen van die eindgebruikers. MRSA-net blijkt protocolinformatie makkelijk en snel beschikbaar te maken. Daarnaast kan het als een leer/leesomgeving dienen. Gebruik in de praktijk liet daarnaast zien dat het noodzakelijk is in kaart te brengen hoe de (informatie) technologie daadwerkelijk gebruikt zal worden en of het past in het werk of dagelijks leven van de gebruiker.

In het onderzoek beschreven in hoofdstuk drie is de duurzaamheid van de websitestructuur van MRSA-net bestudeerd, met als doel de robuustheid van card sorting als onderzoeksmethode vast te stellen. Card sorting is een HCD methode die in de ontwikkeling van MRSA-net werd gebruikt om inhoud (informatie) te structureren. Deelnemers uit alle vier de doelgroepen van MRSA-net (Duits/Nederlands, zorgverlener/algemeen publiek) sorteerden zoekopdrachten die door gebruikers in de zoekmachine van de website waren ingegeven. De sorteringen van deze informatieverzoeken bevestigden deels de structuur van de website, maar lieten ook

verschuivingen in de informatiebehoefte en in de mentale modellen zien. Dergelijke informatie kan gebruikt worden om te bepalen welke zaken in protocollen uitgewerkt moeten worden; zoals een verschuiving naar informatie over zaken die zich buiten het ziekenhuis afspelen en waar huidige protocollen nauwelijks op ingaan. Het bevestigt het beeld dat technologie nooit 'klaar' is.

Naast het bepalen en structureren van de benodigde inhoud, is het belangrijk dat de technologie goed past in de klinische praktijk of de context waarvoor zij bedoeld is. In hoofdstuk vier beschrijven we een systematische literatuurstudie naar de wijze waarop klinische MRSA-richtlijnen in de praktijk geïmplementeerd worden, om een overzicht van de best werkzame implementatiestrategieën te verkrijgen. De implementatie van richtlijnen blijkt echter nauwelijks onderwerp van klinische publicaties te zijn. In de artikelen die beschrijven hoe een bepaalde richtlijn in de praktijk geïmplementeerd is, zijn audit en feedback, herinneringen (reminders), en educatieve bijeenkomsten het meest genoemd. Er zijn echter weinig artikelen die ingaan op de context waarin dergelijke strategieën worden ingezet, en welke omstandigheden uiteindelijk voor de adoptie en correcte uitvoering van de maatregel zorgen. Meer inzicht in de context, in de betrokken stakeholders bij een procesverandering (zoals een nieuwe richtlijn), en in onderzoek naar de effecten van een bepaalde implementatiestrategie op gedrag en klinische uitkomsten is noodzakelijk.

In hoofdstuk vijf beschreven we hoe de eerste fasen van de CeHRes Roadmap, de contextuele verkenning (contextual inquiry), waardespecificatie (value specification) en ontwerp (design) van de antibiotica-applicatie⁴ (app) zijn uitgevoerd. De verkennende onderzoeken (deskresearch, focusgroepen, observaties) leidden tot de identificatie van een doelgroep (verpleegkundigen) die in protocollen over antibiotic stewardship niet of nauwelijks genoemd is, terwijl deze doelgroep in het proces van antibioticagebruik een belangrijke rol speelt. De studies uit hoofdstuk vijf gaven verder inzicht in de werkzaamheden (taken, rollen) en behoeften (ondersteuning, informatie) van de stakeholders in dit proces (o.a. verpleegkundigen, artsen, apothekers, microbiologen). Deze informatie, aangevuld met evaluaties van een prototype, een card-sort-studie en gebruikerstesten leidden tot de ontwikkeling van de antibiotica-app⁴. Deze app biedt informatie die verpleegkundigen nodig hebben om hun antibiotica-gerelateerd werkzaamheden uit te voeren, zoals protocollen voor het intraveneus toedienen van antibiotica. De app biedt de informatie in een toegankelijke, gemakkelijk toepasbare vorm. De HCD methoden die ingezet werden om de app te ontwikkelen leidden daarnaast tot een discussie over de rol en taakopvatting van de verpleegkundigen.

De evaluatie van de antibiotica-app in hoofdstuk 6 liet zien dat de app een positieve gebruikservaring (user experience) en verbeterde efficiëntie (tijdswinst) oplevert bij het zoeken van informatie. De evaluatie liet verder zien dat het bevorderen van de emancipatie van verpleegkundigen geen gemakkelijk proces is; een gedegen

informatievoorziening is slechts één aspect van de te veranderen infrastructuur en werkcontext. Het via de app toegankelijk maken van informatie die voorheen niet beschikbaar was voor verpleegkundigen heeft geleid tot een discussie over de rol van verpleegkundigen in antibiotic stewardship; hebben zij een rol, en zijn zij daartoe voldoende uitgerust?

Hoofdstuk zeven geeft inzicht in het daadwerkelijke gebruik van de app via een logdata-analyse. Uit de analyse van de gebruiksdata en van de opmerkingen die gebruikers tijdens evaluatietesten maakten, blijkt dat de applicatie vooral voorziet in taakondersteuning (task support), een strategie uit het Persuasive Systems Design Model⁵. Dit model beschrijft op welke wijzen technologie kan motiveren en gedrag kan sturen. Doordat het gemakkelijker is informatie te zoeken met de app, gaven veel verpleegkundigen de voorrang aan het gebruik van de app boven de traditionele informatiebronnen. De logdata lieten een verband tussen gebruiksmomenten en antibiotica-momenten in het zorgproces zien, zoals verhoogd gebruik van de app op de tijden van de medicatie-rondes, wat duidt op daadwerkelijke inpassing in het zorgproces.

De studies beschreven in dit proefschrift demonstreren hoe human-centered design en een focus op context en stakeholders via de CeHRes Roadmap geoperationaliseerd kunnen worden. Het onderzoek laat zien dat continue evaluatie belangrijk is om tijdens en na de ontwerpfasen te kunnen blijven inspelen op de behoeften van de doelgroep en de steeds veranderende context.

De stappen die gezet werden om de behoeften van gebruikers en de context van de technologie in kaart te brengen en om technologie beter beschikbaar te maken via de app, hebben hiaten in het zorgproces zichtbaar gemaakt. De app leidde tot een discussie over wie precies verantwoordelijk is of zou moeten zijn voor bepaalde taken zoals het monitoren en signaleren van suboptimale behandeling en het tijdig wijzigen van beleid. Daarnaast bleek het onduidelijk wie verantwoordelijk zou moeten zijn voor het up-to-date houden van informatie en afstemmen van informatie op de behoeften van de gebruikers. Deze onduidelijkheden waren niet eenvoudig oplosbaar. Het onderstreept de definitie van eHealth door de EU⁶: eHealth is het gebruik van ICT in producten, diensten en processen, gecombineerd met organisationele verandering in systemen en vaardigheden, met als doel gezondheid van burgers te bevorderen. Dus, ontwikkeling van eHealth kan helpen aan een (informatie) behoefte te voldoen, maar het ontwerpproces kan ook de benodigde verandering van de zorg op sommige aspecten blootleggen.

Ons onderzoek heeft aanknopingspunten voor verder onderzoek opgeleverd. Hierbij noemen we expliciet de rationale voor het opnemen van persuasieve strategieën in eHealth, in een professionele (gezondheids)context. Ook spelen logdata een belangrijke rol bij het ontwerp en de evaluatie van eHealth-toepassingen. Door de logdata-analyse konden we vaststellen in dat de app daadwerkelijk in de praktijk gebruikt werd. Ook liet de

logdata-analyse zien welk type inhoud bekeken werd. Hierdoor, en door opmerkingen van gebruikers werd duidelijk dat de app vooral ondersteunend was bij de uitvoering van (standaard) taken. Vervolgonderzoek kan helpen vaststellen hoe emancipatie van verpleegkundigen en het bevorderen van hun nieuwe rol in antibiotic stewardship kan worden gestimuleerd door persuasieve eHealth-technologie (eLearning).

Met betrekking tot de onderzoeksvragen concluderen we dat de antibiotica-app, qua vormgeving en inhoud, verpleegkundigen ondersteunt bij hun antibiotica-gerelateerde taken. Door herinrichting van reeds bestaande informatie volgens een taakgerichte indeling in een gemakkelijk toegankelijke app worden de noodzakelijke voorwaarden voor besluitvorming geschapen. De app is gemakkelijk toegankelijk vanuit de systemen die al gebruikt worden en is daardoor goed in te passen in het werkproces. Voor een volledige en duurzame implementatie is brede ondersteuning vanuit de organisatie nodig. Daarbij is organisatiebreed beleid ten aanzien van antibioticagebruik vereist, waarbij aandacht is voor conflicterende belangen van stakeholders. De methodieken die zijn toegepast hebben geleid tot succesvolle identificatie en formulering van requirements⁷. Daarnaast leidden de methoden tot inzichten in het zorgproces omtrent antibiotica die tot dusverre onbesproken zijn in de literatuur (de rol van verpleegkundigen in stewardship) en bieden daarmee een belangrijke bijdrage voor een socio-technische aanpak binnen zorgprocessen waarin er meer aandacht voor de zorgverleners en hun context is. Niet alleen bij het ontwikkelen van technologie is een dergelijke aanpak belangrijk; de methodieken bleken ook voor bijvoorbeeld protocolontwikkeling een belangrijke meerwaarde te hebben. Ze stelden ons in staat behoeften van gebruikers te identificeren en daarop aan te sluiten. De methodieken van de CeHRes Roadmap maakten het mogelijk belangen en behoeften af te wegen. De meerwaarde van de Roadmap lag vooral in de stakeholdergerichte aanpak, waarbij resultaten en bevindingen op iteratieve basis aan verschillende stakeholders werden voorgelegd ter bevestiging. De aanpak resulteerde in een verbetering van de efficiëntie van het primaire proces: verpleegkundigen waren sneller in staat informatie over antibiotica te vinden voor het uitvoeren van hun primaire taken.

De motivatie voor het onderzoek beschreven in deze thesis werd gevormd door de doelstelling van EurSafety-Health-Net: verbetering van patiëntveiligheid door verantwoord antibioticagebruik. Wij stellen vast dat verbetering van patiëntveiligheid niet zozeer afhankelijk is van de inzet van meer technologie, maar in de eerste plaats van een goede samenwerking en informatie-uitwisseling tussen zorgverleners, patiënten en andere stakeholders. Technologie kan de infrastructuur bieden om dit te bereiken. De personen die de betreffende zorgprocessen uitvoeren of erdoor geraakt worden, moeten centraal gesteld worden om duurzame verandering te kunnen bereiken. Al bij de ontwikkeling van MRSA-net werd vastgesteld hoe belangrijk een focus op de gebruiker is,

en in het huidige onderzoek hebben we daaraan toegevoegd dat oog voor de context (inclusief relevante stakeholders) daar ook bij horen. Hiermee stopt het niet. In andere promotietrajecten (deels parallel lopend aan het huidige) worden business modelling en de mogelijkheden van persuasieve ontwerpen verder onderzocht. Daarnaast hebben de ervaringen van EurSafety-Health-Net geleid tot drie nieuwe grensoverschrijdende projectinitiatieven:

- Health-i-care, een project dat zich richt op samenwerking tussen het midden- en kleinbedrijf en de wetenschap voor verbeterde patiëntveiligheid. Het project richt zich vooral op innovaties voor infectiepreventie en preventie en diagnostiek van Bijzonder Resistente Multi-Organismen (BMRO).
- EurHealth-1Health is een project waarin ernaar gestreefd wordt door samenwerking toekomstige risico's met betrekking tot antibioticaresistentie (met name carbapenemresistentie) voor burgers in de grensregio's te verlagen. Om gezondheid te bevorderen zal de grens tussen de humane en de veterinaire wereld en de milieu/waterwereld overstegen moeten worden, door samenwerking tussen wetenschap en zorginstellingen.
- CommonCare, een project waarin grensoverschrijdende zorgpaden worden ontwikkeld om een optimale kwaliteit van behandeling te bereiken.

Deze projecten bieden nieuwe kansen om grenzen te vervagen en te profiteren van een gezamenlijke aanpak.

1 <http://www.utwente.nl/iqs/ehealth/>

2 <http://beta.infectionmanager.com>

3 www.eursafety.eu

4 <http://abnurseapp.infectionmanager.com/>

5 Oinas-Kukkonen, H. and M. Harjumaa, *Persuasive systems design: Key issues, process model, and system features. Communications of the association for Information Systems*, 2009. 24(1): p. 485-500.

6 European Commission, *eHealth Action Plan 2012-2020 - Innovative healthcare for the 21st century*, 2012, European Commission: Brussels.

7 Van Velsen, L., J. Wentzel, and J.E. Van Gemert-Pijnen, *Designing eHealth that matters via a multidisciplinary requirements development approach. JMIR research protocols*, 2013. 2(1).

Dankwoord

Nu de uitkomsten van mijn onderzoek van de afgelopen >4 jaar op papier staan, sta ik met veel plezier stil bij alle hulp die ik heb gekregen om dit promotieonderzoek te voltooien. Ik kom tot de gelukkige conclusie dat ontzettend veel mensen op de een of andere manier hebben bijgedragen aan mijn promotietraject. Promoveren kun je niet alleen doen, dus zonder alle hulp was het zeker niet gelukt. Advies bij het opzetten en uitvoeren van het onderzoek, deelname aan de onderzoeken, proofreaden van artikelen en feedback geven op (poster)presentaties, morele steun (een luisterend oor), een inspirerend voorbeeld, hulp thuis, en tijdige afleiding en entertainment; de manieren waarop ik mij gesteund en geholpen voel zijn talrijk. Hierbij werden niet zelden traditionele grenzen overschreden: het thuisfront betrok ik meer en meer in de inhoud van mijn onderzoek, en met collega's bleek ik uitstekend niet-werk gerelateerde activiteiten te kunnen doen ter afleiding. Ik wil een aantal mensen in het bijzonder hier noemen.

Allereerst bedank ik mijn promotor, Lisette. Als afstudeerbegeleidster zag zij toen ik afstudeerde op een evaluatieonderzoek naar de Dieetcoach van Medinfo voldoende potentieel in me om mij te vragen om een promotieplek binnen EurSafety Health-net te bekleden. In mijn herinnering begon het allemaal wat vaag en met enige vertraging. Dit vroeg van mijn kant vertrouwen: Zou het wel echt rondkomen? En wat gaan we dan precies doen? Ik geloof dat het leren omgaan met onzekerheden en toch je eigen koers varen, en je altijd aanpassen aan nieuwe ontwikkelingen de meest belangrijke vaardigheden zijn die ik van jou, Lisette, heb mogen leren. Vertrouwen lijkt daarin een kernwaarde te zijn. Ik heb bij jou nooit enige twijfel bemerkt over of het wel zou gaan lukken allemaal, en of ik er wel uit zou komen. Daarvoor ben ik je dankbaar, het gaf me zelfvertrouwen. Het deed me natuurlijk ook enorm twijfelen: Het kon toch niet zo zijn dat jij niet zag wat ik allemaal niet goed deed?

Mijn twee copromotoren, Alex en Robbert, wil ik bedanken voor de bijdragen die zij hebben geleverd. Alex, je hebt als inspirerend chef de mission van het EurSafety-avontuur altijd voor enthousiasme en vertrouwen in de bijdragen van die gekke klik uit Twente gezorgd. Ik ben blij dat ik deel uitmaak van het grensoverschrijdend netwerk wat jij gecreëerd hebt. Robbert, jou bedank ik voor de begeleiding die je me hebt gegeven bij het schrijven van artikelen, plannen, en afronden van het proefschrift. Ik vond het erg prettig te kunnen overleggen met iemand die met een frisse, pragmatische blik keek naar de voortgang. Hoewel pas op een later moment in beeld kwam in mijn onderzoek, heb je me een flinke nudge gegeven om alles netjes en min of meer volgens planning af te maken.

De leden van de promotiecommissie ben ik uiteraard ook zeer dankbaar. Ik ben blij en vereerd dat zij zitting in mijn commissie wilden nemen, en mijn proefschrift hebben beoordeeld. Prof. dr. M. Jaspers, dr. R. Hendrix, Prof. dr. H. Hermens, Prof. dr. E. Bohlmeijer, dr. S. Kelders, bedankt voor de tijd en moeite die jullie gestoken hebben in de

beoordeling van mijn manuscript, en jullie aanwezigheid bij de verdediging. Prof. dr. H. Oinas-Kukkonen, *kiitos* for the time and effort you invested in reading and judging my thesis, and for being part of my committee.

De Eursafety-Twente groep, onder aanvoering van Lisette en Ron, zijn een groot bedank waard. We vergaderden in het begin op vrijdagochtend over de invulling van het project en onze onderzoeken, waarna Maarten en ik nog een middag hadden om enigszins bij te komen en de nieuwe plannen en visies verder uit te werken. Het werd mij al snel duidelijk dat nog even een biertje doen in de stad op donderdagavond echt niet meer kon; op vrijdag was het knallen geblazen. Lisette, ook in deze context, als Eursafety sparring-partner en soms antagonist van Ron, heb je mij zeer geïnspireerd. Je had talloze goede ideeën voor onderzoeken, samenwerkingspartners (die wij dan, als het even kon in het Duits, mochten benaderen), en visies. En, niet onbelangrijk, we hebben enorm veel plezier gehad en heel wat afgelachen. Op congres gaan met jou was bepaald geen relax-vakantie, maar ik vond het altijd enorm leuk. Het was spannend; zowel overdag op het congres als 's avonds aan de bar was je present. Je energie werkt aanstekelijk, ik kijk met veel plezier op onze avonturen in binnen en buitenland terug. Ron, hoewel je me onlangs nog vertelde dat specifieke dankbetuigingen altijd een beetje ongemakkelijk zijn, omdat ook de niet bij naam genoemden vaak minstens zo nuttige bijdragen leveren (wat waar is!), ga ik jou wel in het bijzonder bedanken. Wat ik fijn vind aan onze samenwerking is dat jij een flinke discussie zeker niet uit de weg ging. Wat een uitdaging was het om jou van gedachten te doen veranderen. Dat lukte ook zeker niet altijd, wat soms resulteerde in leren compromitteren voor mij. De debatten en daaruit voortvloeiende geniale inzichten zijn altijd gebleven, ook toen we op maandag (en later woensdag) gingen overleggen (pizza-overleg!). Maarten, we traden samen toe tot de wondere wereld van EurSafety, onder zeer gewaardeerde begeleiding van Fenne en gesteund door een cursus Duits, die misschien toch iets te 'abgespeekt' was voor onze behoefte. Dank voor je gezelschap en de samenwerking. Ik denk dat we kunnen stellen dat we al dan niet onder het genot van een (één?) biertje, veel hebben kunnen doen. Fenne, ik werd niet zelden als 'de nieuwe Fenne' geïntroduceerd, omdat mijn onderzoek voortbouwt op het mooie werk wat jij met MRSA-net hebt neergezet. Door jouw enthousiasme en warme, fijne persoonlijkheid, werd ik zelf enthousiast voor het doen van een promotieonderzoek. Bedankt voor je inspiratie en de begeleiding die je me hebt gegeven in het begin. Ik vond het ontzettend jammer dat je op een gegeven moment (om zeer begrijpelijke redenen!) naar de HU ging. Ik hoop dat mijn proefschrift een waardig opvolger van het jouwe is, en ik ben blij dat op de (te) schaarse moment dat we elkaar zien het als vanouds gezellig is! Nienke, jij bent iets later toegetreden tot het EurSafety team, tot mijn grote blijdschap. Tijdens je student-assistentenschap en afstuderen merkten we al dat we goed samen konden werken, met mooie resultaten tot gevolg. En, niet geheel onbelangrijk, het was nog enorm gezellig ook. De meerwaarde van een goede 'match' (collega-wise) qua samenwerking hebben we nog

vaak ervaren (Brainwave! resulterend in >100 mailtjes heen en weer). Daarnaast ben ik blij dat je een goede vriendin van me geworden bent, die begaan is met ups en downs die binnen en buiten de UT in mijn leven voorbij komen. Ik ben erg blij dat je mijn paranimf wil zijn, we hebben veel samen gedaan en weet soms nog beter dan ik waarom het onderzoek heb gedaan zoals ik het heb gedaan. Hopelijk (op het moment van schrijven zit je mini-me nog veilig in je buik), staat je nageslacht het je toe ook tijdens de verdediging mij bij te staan. Maar als niet, dan toch, want je hebt me al zoveel geholpen gedurende de afgelopen jaren, dat dat vast nog even doorwerkt. Ik hoop dat je kunt en zult genieten van het geluk wat je te wachten staat!

Alle deelnemers aan mijn onderzoek en andere betrokkenen, mijn zeer belangrijke stakeholders, wil ik bedanken voor de medewerking die zij mij meermaals hebben gegeven. Ik vind het bijzonder dat jullie hiervoor tijd en moeite hebben opgeofferd en waardeer dat zeer. Hierbij noem ik natuurlijk de artsen en verpleegkundigen van de longafdeling van het MST (verpleegafdeling A4 en C4), apothekers Regine van Drie-Pierik en Lars Nijdam, de collega's van de afdeling medische microbiologie van het UMCG (o.a., Jerome, Jan-Willem, Bhanu, Alex, Anja).

Lieve (ex)collega's van de eHealthgroep, jullie hebben zowel inhoudelijk als qua vriendschap en sfeer enorm bijgedragen aan dit proefschrift. Lisette, Hans, Olga, Annemarie, Saskia K, Nicol, Fenne, Joyce, Nienke N, Nienke BdJ, Saskia A, Floor, Maarten, Liseth, Roos vdV, Lex, Marjon, Robin, en Elly, bedankt voor alle hulp (met ideeën, schrijven, stoom afblazen), en leuke (congres)ervaringen die we samen hebben gehad. Laat ik het nu zwart op wit registreren: nee, ik was niet mee naar St. Maarten (!!). Maar tijdens congressen en cursussen waar ik wel bij was in o.a. Guadeloupe, Valencia, Barcelona, Padua, Potsdam, Londen, Groningen, en in de Grolsch Veste heb ik gemerkt wat een superteam we zijn, dat naast innovatief werk, ook goed de bar overeind weet te houden. Top!

Alle collega's van PGT wil ik bedanken voor de fijne samenwerking die we hebben gehad in de afgelopen jaren. Marieke, in het bijzonder bedank ik jou voor al je hulp bij alles, zorgt er altijd voor dat alles goed geregeld is, een geruststelling! Verder heb ik onze groep als erg open en toegankelijk ervaren; ik ben bij velen van jullie wel eens binnen gelopen om een vraag te stellen, hulp te vragen, of om een gezellig praatje te maken. Ik neem me voor dat voorlopig te blijven doen! Ik kijk met plezier terug op de goede onderlinge sfeer en de vele activiteiten die we samen (in wisselende samenstelling) doormaakten: o.a., kerstdiners, vakgroepsvergadering en -uitjes – al dan niet inclusief speurtocht!, borrels, congressen, en de zeskamp. Daarnaast werd er nog wel eens een aanleiding aangegrepen (het einde van een door ons georganiseerd congres/collegejaar/gewoon, vrijdagmiddag) om een hapje te eten of een borrel te drinken, waarna we toch telkens concluderen dat we dat vaker moeten doen.

Lieve aio's van de torenkamer, tegelijk met (de meesten van) jullie begon ik met mijn baan als onderzoeker aan de UT. We deelden lief en leed met elkaar op deze ronde

kamer met panorama-views. Hoewel het soms een uitdaging was voor mij om niet teveel afgeleid te raken van zoveel gezelligheid (en activiteit) op een kamer, ben ik blij dat we bij elkaar hebben gezeten en talloze discussies te ver hebben doorgevoerd. Met de klok mee, vanaf de deur: Ingrid, Roos A., Liseth, Martijn, Anne Marie, Maarten, Hester, Elly, en later ook Olga, Nadine, en Laura: bedankt, het was super om zulke kamergenoten te hebben. Dat geldt zeker ook voor de gezellige tijd met Maarten, Olga, Floor, en Marit met wie ik op verschillende momenten in wisselende samenstelling een kamer deelde. Naast gezelligheid op de kamer werd er pas echt even goed bijgekletst tijdens de pauzes in de Waaier, het Theatercafe, of de Gallery. Pauze-genootjes, ik heb tot het laatst m'n schaarse bezoeken aan de groep zo geprobeerd in te plannen dat ik deze fijne moment niet hoefde te missen en gelukkig blijf ik nog even in de buurt, dus het komt er hopelijk nog geregeld van!. Roos A., Anne Marie, en Hester, nu we elkaar iets minder vaak treffen, blijkt het belang van het in stand houden van etentjes/borrels maar weer, want als we elkaar zien zijn 10 min niet genoeg om even bij te praten. De daghap houden we erin! Floor, Laura, Nadine en Nienke, ook met jullie blijkt dat gezelligheid geen tijd kent. Zowel tijdens etentjes, bruiloft, als congresbezoek (Barcelona!) houden we het goed met elkaar uit. Ik bof met zulke collega-vriendinnen. Floor, bedankt dat jij mijn paranimf wil zijn. Je hebt me al met zoveel dingetjes geholpen, en eerlijk advies gegeven. En ik maak graag gebruik van je hulp en de aanleiding om ff op je kamer langs te komen. Dat komt vast ook doordat het erg gezellig is om samen met jou dingen te regelen ;-).

Los van UT-gerelateerde steun en gezelligheid, heb ik veel gehad aan de leuke momenten met vrienden, waardoor ik het werk even kon (moest) loslaten. Lieve vrienden van LeMetropolitain, jullie zorgen al zo'n 15 jaar voor ontspanning en gegarandeerd plezier tijdens de activiteiten die we, hoewel we wat uitgewaaierd zijn over Nederland en de rest van de wereld, gelukkig nog altijd ondernemen. Daarom dank ik Berdien, Femke, Janine, Jetty, Julie, Manon, Marjolein, Renske, Saskia, Sonja, Sovianne (top illustratie!), Bart, Luuk, Mathieu, Redmar, Rob, en Sven, en alle aanhang, voor de fijne momenten samen. De weekendjes, kerstdiners, heerlijk avondjes en alle andere activiteiten, bijzonder en fijn dat we dat allemaal nog steeds met veel plezier doen. Verder bedank ik mijn sportmaatjes Janine en Liesbeth, we begonnen onze ontspanningssessies met yoga op de UT. Steps, bodypump, baantjes trekken, hardlopen.... van gezamenlijk sporten komt inmiddels weinig meer terecht, maar de weekendbrunches kunnen wat mij betreft nog een tijd mee. Dank ook voor het delen van jullie eigen (promotie en werk) ervaringen, en de gezelligheid. Verder bedank ik Bart, en Theun, Maarten, en Suus voor hun gezelligheid, hulp, en een goede reden om de fiets/auto/vliegtuig te pakken voor een kop koffie of kraambezoek ☺. Wendy, Laura, Lianca, Kelly, en Maartje, jullie wil ik bedanken voor jullie vriendschap, interesse en betrokkenheid. We hebben het altijd leuk tijdens actieve of minder actieve sessies, maar het is ook belachelijk hoe weinig we in de gelegenheid zijn elkaar te zien. Maartje, wij brengen daar in elk geval verandering in; super om je kamergenoot te zijn!

Brechje, bedankt voor jouw vriendschap. De momenten waarop je een luisterend oor voor me bent (ok, andersom komt ook wel eens voor), luister je ook echt.

Naast vriendschap blijkt familie ook een belangrijke motiverende kracht voor het doorzetten. Schoonouders Gerry en Dick, en schoonzussen en zwagers Birgit, Kirsten, Han en Peter, dank voor jullie interesse, hulp, en de fijne momenten in Enschede of Drenthe. Mijn prachtige nichtjes en neefje Maysie, Laurinda en Davis wil ik niet ongenoemd laten: het wordt steeds gezelliger met de nieuwe generatie erbij!

Papa en mama, in mijn beleving heb ik jullie tijdens het hele proces nooit zo vreselijk veel over mijn werk en onderzoek verteld. Jullie toonden altijd interesse, maar even niet over het werk praten was ook helemaal prima en dat was erg fijn. Jullie hebben mij de bagage gegeven die zeer goed van pas is gekomen; het hoofd een beetje koel kunnen houden en gezond verstand gebruiken, je interesse volgen. Het hielp me de stress buiten de deur te houden. Af en toe ontstond er wel eens wat paniek, met name op het laatst (er is geen proefschrift wat zonder enige stress ontstaat), maar ik heb het gevoel dat ik mede dankzij jullie voorbeeld een goede balans heb weten te vinden en vast te houden. Tijd voor elkaar, en een fijn thuis zijn een belangrijke basis. Daarvoor kan ik jullie niet dankbaar genoeg zijn.

Renske, Marjolein en Thomas, ik ben enorm blij met mijn twee geweldige zussen en zwager. Enschede is niet echt naast de deur, maar we gaan voor kwaliteit boven kwantiteit in de tijd die we samen zijn en daarin zit het eigenlijk altijd goed. De toekomst belooft qua logistieke uitdaging een verbetering. Gelukkig, want heb mijn zussen best dichtbij me gemist, gedurende de tijd in Twente. Renske, ik ben natuurlijk extra blij dat jij als paranimf me bijstaat bij de laatste fase van mijn promoveren. Ik vond het fijn dat je geïnteresseerd was, en ook regelmatig met suggesties kwam of me op ontwikkelingen attendeerde. Ik had het niet meer verwacht, maar zelfs op professioneel vlak hebben we nog wel eens voor een persoonsverwarring gezorgd, dat komt vast niet alleen door de uiterlijke gelijkenis 😊.

Dit proefschrift was misschien een stuk moeilijker af gekomen, als wij niet terug hadden kunnen vallen op ons oppas-team (Renske, Gerry, Dick, papa en mama). Ook iets meer incidentele oppastantes en ooms wil ik bedanken. We maken graag gebruik van jullie hulp, Esmé is er zeker ook blij mee, maar ik vind het niet vanzelfsprekend. Ik ben blij dat jullie ons hiermee helpen, het heeft voor Erwin en mij een groot verschil gemaakt!

Lieve Er, wat halen we ons samen toch telkens op de hals. Voor 2015 hadden we vanalles op het programma staan, en er lijkt nu zowaar een soort van einde inzicht te komen. Het lijkt soms wel of het ons allemaal maar een beetje overkomt en of het niet zo erg doordacht is allemaal. Een planning voor ons leven hebben we ook eigenlijk niet echt (kan dat eigenlijk wel?). Ondanks dat allebei promotieonderzoek doen, een prachtig kindje, en werk in Enschede en Groningen misschien niet het meest logische combinatie is, lukt het ons tot nu goed. Volgens mij komt dat doordat we het goed hebben samen.

Bedankt voor het aanhoren van mijn verhalen (incl. frustraties) en het doorstaan van mijn grillen. Jij helpt me, houdt me in balans, en maakt me gelukkig. Samen kunnen we nog heeeel lang door, op naar alle nieuwe dingen die ons vast weer overkomen...

Wat een geluk dat Erwin en ik het leukste kindje ter wereld hebben gekregen. Esmé, je hebt niet echt een benul van wat je vader en ik doen (sterker nog, je hebt pas recent het benul ontwikkeld om ons consequent correct te benoemen), maar jij motiveert me enorm. Je heb een nieuwe dimensie aan mijn leven is toegevoegd, en laat me zien hoeveel ik eigenlijk kan (samen met je papa). Jij was een relaxte baby, we konden rustig wennen aan de nieuwe gezins-dynamiek (Joris en Paulus ook). Nu manifesteert jouw onderzoekende en actieve aard zich, wat iets minder gemak, maar wel nog meer plezier met zich meebrengt. Dat gaat dus gewoon door, wat fijn! Wat een lief esmeesje ben je.

Publications & other output

Journal articles (peer-reviewed)

- van Limburg, M., Wentzel, J., Sanderma, R., & van Gemert-Pijnen, L. (2014). Business Modeling to Implement an eHealth Portal for Infection Control: A Reflection on Co-Creation With Stakeholders. *JMIR research protocols*, 4(3), e104-e104.
- Wentzel, M.J., Jong, N. de, Nijdam, L., Drie-Pierik, R. van & Gemert-Pijnen, J.E.W.C. van (2014). Understanding eHealth use from a Persuasive System Design perspective: an Antibiotic Information Application for Nurses. *International journal on advances in life sciences*, 6(3&4), 210-219.
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- Velsen, L.S. van and Gemert-Pijnen, J.E.W.C. van and Beaujean, D., Wentzel, J. and Steenbergen, J. van (2012) Should Health Organizations Use Web 2.0 Media in Times of an Infectious Disease Crisis? An In-depth Qualitative Study of Citizens' Information Behavior During an EHEC Outbreak. *Journal of medical internet research*, 14 (6). e181. ISSN 1439-4456
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Book chapter

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Other output

Nurse antibiotic app – demo via <http://abnurseapp.infectionmanager.com/>

Infection manager - <http://beta.infectionmanager.com>

Blended care instrument - http://www.utwente.nl/igs/ehealth/project_output/fit-for-blended-care/

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Jobke currently works at the department of Media, Communication and Organization of the University of Twente. Here, she conducts research in a postdoc project, focused on making wearable technology (e.g, smart glasses such as Google glass) accessible for people with a disability, such as visually impaired persons.