Antibiotic Information App for Nurses

Development and Preliminary Effects

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***Abstract*—Antibiotic stewardship programs aim to optimize antibiotic use in order to control antibiotic resistance. Nurses need easily accessible information on antibiotics to perform antimicrobial-related tasks optimally. A task supporting antibiotic information application was developed to support nurses. With log file analysis, scenario-based tests and information behavior questionnaires we evaluated the app. The results show steady, continuing use. Instruction pages are most popular, and first responses to the application are positive regarding look and feel and accessibility of information.**

Keywords-eHealth; antibiotic stewardship; nurse; task-support

I. INTRODUCTION

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. To stop resistance forming and preserve their effectiveness, prudent use of antibiotics is needed [1]. 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. 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. Nurses spend much time caring for and observing patients, they are the eyes and ears of the physician and notice changes in patient status that call for antibiotic therapy adjustment.

In earlier research, we already identified nurses as an important stakeholder for ASPs [2], even though scientific literature on ASPs focuses mainly on physicians and clinical experts [3]. 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 into account user needs and provides bed-side task support.

Information and communication technology holds the promise of facilitating information transfer and offering support in a variety of health care settings [4, 5]. Applications aimed to support health care workers (HCWs) are abundant, both in mobile applications (for smartphone or tablet) or websites and web apps [6]. However, sometimes apps 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 [7-9]. In some cases, taking a more user- or practice- based focus throughout the design phases may help to overcome these difficulties [8, 10]. Also, incorporating persuasive system design into technology may help to improve uptake and effectiveness. In this model, the targeted behavior is reinforced, shaped or changed by the technology, thereby 'persuading' its users [11]. 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 quickly reach their goals [11]. With regard to nurse support in antimicrobial 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. We suspect 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, which is a barrier for nurse empowerment in ASP [2]. Based on this understanding of the work context, we developed an application.

In this paper, we describe preliminary summative evaluation results of an antibiotic information app for nurses, by focusing on actual use and effects of use on antibiotic stewardship-related tasks. The following research questions guided this research:

1. How is the application being used?
2. Does the application support nurses in their antibiotic-related tasks?
3. Is app-use more efficient than standard information sources ?
4. How do nurses experience the use of the app?

II. THE ANTIBIOTIC INFORMATION APP

Based on formative evaluations, the antibiotic information app was developed [12]. In focus groups, interviews, scenario tests and usability tests nurses in our

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pilot research expressed a need for an easily accessible, centralized information application, where they could find all information on the use of antibiotics they need during their work. This included 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). First, a prototype was created in WordPress [13], with some alterations to fit our specific content management demands. Based on its evaluations a final release was launched. The application is web-based, and can be run from the hospital's own server. However, for the pilot the system was made available via the internet, and was taken up in the nurses' personal hospital start page so that it could be accessed easily. Besides PC, the application is optimized for mobile (tablet, smartphone) use. For the app's content, the information sources that were already used by the nurses served as input. These sources were 'chopped up', 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 expert, irrelevant and confusing to nurses). The different types of content are ordered according to the mental models of the nurses as they resulted from the card-sort study. Information is grouped by the following categories: information needed to perform the primary tasks, important information and warnings, general or background information, extra checks and safety information, and information for specialists and medical background (see Figure 1). A demo version (in Dutch) of the app can be accessed via [14].

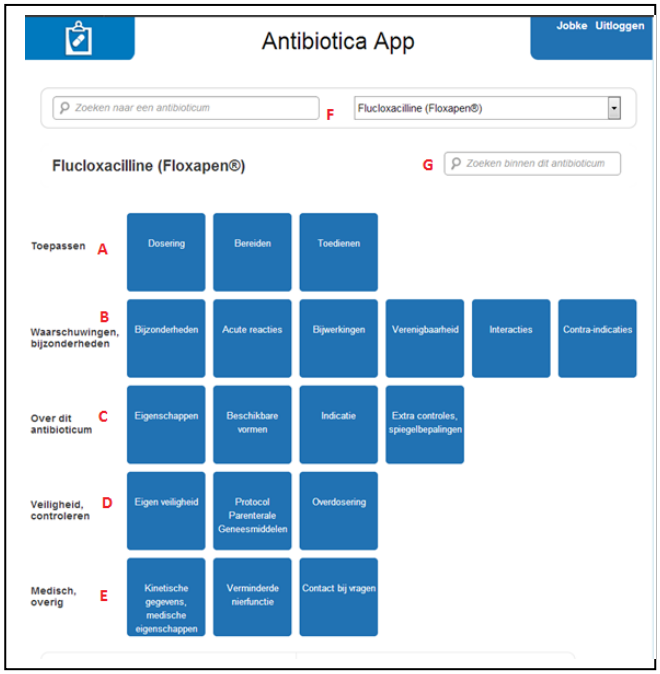

Figure 1. Screenshot of antibiotic overview page. A: task instructions, B:important information and warnings, C: general or background information, D: Safety checks and quality control, E: information for specialists and medical background, F: search field for antibiotic or select from list, G: search all pages (per antibiotic).

By providing easily accessible information, nurses may be better equipped to perform antibiotic related tasks, and are able to recognize and address instances of suboptimal antibiotic use. This supports improved knowledge and recognition of instances to optimize antimicrobial use and nurse empowerment to discuss patient therapy and alert physicians in case of suboptimal antibiotic use. Figure 2 shows an instruction page of the application, where nurses can read how to administer a certain antibiotic, including what to pay extra attention to.

Figure 2. Screenshot of antibiotic overview page. A:back-button B: print and email buttons, C: search field, D: breadcrumb trail, E: instruction block on administration, F: source of the information with link, G: information on last update of the information block

III. METHODS

A. *Participants*

Two lung wards of a local 1000-bed teaching hospital participated in this research. The wards have total of 57 beds. During the pilot phase, 62 nurses (45 FTE) worked at the two wards. A number of them were informed about the app and the importance of antimicrobial stewardship in presentations, all received an email with instructions and instructional fact-sheets on antimicrobial stewardship and the app were distributed repeatedly throughout the wards.

B. *Information behaviour questionnaire*

We created a questionnaire to measure satisfaction and usability of information sources. In addition, items to measure to what extent nurses feel secure and confident to report and discuss suboptimal antibiotic use were added to the questionnaire. The questionnaire consists of existing scales that we adapted to better fit our research questions: To measure to what extent nurses feel supported by the information supply and its usability we adapted parts of Persuasive Systems Design (PSD) questionnaire (task support, persuasiveness, unobtrusiveness) [15, 16], and the

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Website Evaluation Questionnaire (WEQ): relevance, user friendliness, hyperlinks, speed [17]. To measure to what extent nurses feel confident to discuss antibiotic therapy suggestions with physicians we used parts of The Organization and Management of Intensive Care Units, by Shortell and Rousseau (openness, accuracy, understanding) [18], and the Safety Attitudes Questionnaire (teamwork climate) [19]. Lastly, four ASP-specific items and seven items to measure demographics and internet experience [20] were added. Questionnaire items that were originally in English were translated into Dutch and back-translated into English to check for translation errors. The questionnaire was sent by email, and in case of non-response, up to two reminders were sent.

C. Scenario-based user tests

Ten scenarios were created together with a pharmacist and clinical microbiologist. The scenarios present situations that can arise during the nurse's work, eliciting some information need regarding the (correct) use of antimicrobials. The most critical moments in antimicrobial use, where mistakes are most likely and better information could have prevented them, were translated into cases. The cases addressed e.g. interaction of multiple types of medication, administering two or more medications at the same time, (sub) optimal dose due to abnormal weight, etc.

Sixteen nurses participated in the baseline measurement tests, forty nurses will participate in the post-measurements (consisting of two conditions). The participants vary in age, work experience and gender.

During baseline measurement all nurses had no experience with the antibiotic information app and had to resolve the scenarios relying on their usual information sources. During post measurement (in progress), all nurses will have had >6 months of experience using the app (having had >6 months access to it). One group will be randomized into the condition that they have to resolve the scenarios without the antibiotic information application (thus again using their usual information sources), the other group is allowed to use the application. All participants are presented with a scenario, and asked to give a solution (what would you do/needs to be done). They are asked to perform their information-search activities while talking out loud; e.g., look it up in a computer, ask a colleague, call the pharmacist, etc. This activity is recorded on audiotape as well as video.

The audio and video files are analyzed to determine a) whether the scenario was resolved correctly b) what information source(s) was used c) whether any problems arose during the search; and d) how much time was needed to resolve the scenario.

D. Log-file analysis

The application was introduced at the two pilot wards where users could access the application directly on a pc without login. Mobile use was possible only via login. Throughout the pilot we monitored the use of the app to ensure whether it fulfills information needs, at what moment these needs arise most, and what type of content is viewed. The use of the application is being logged using Google Analytics, as well as a Wordpress (the app's software) plug-in [13]. Log information of interest includes visits per day, time of day with most visits, most frequently viewed content and visit duration.

IV. RESULTS

In this paper, we present preliminary results because post measurements and analysis are ongoing. The available results include log file results and baseline measurements.

A. Information behaviour questionnaire

The baseline questionnaire was completed by 27 nurses (24 women, 3 men) out of 64 nurses that were invited to participate (42%). Their mean age was 36 years old (sd 10.4), and on average they had 8.1 (sd 6.1) years of experience working on their ward, and 12.3 (sd 9.8) years of experience working as a nurse. Their internet experience, as measured by the amount of hours they use the internet per day (work and private use) is 2.7 (sd 2.7) hours.

TABLE I. QUESTIONNAIRE OUTCOMES

Information behavior questionnaire	***Subdomain or scale (number of items)***	***Mean score***
Experience, satisfaction and usability of information	Task support (2)	3.0
	Reliability (1)	2.8
	Persuasiveness (3)	2.9
	Unobtrusiveness (4)	1.9
	Relevance (3)	2.7
	User friendliness (3)	2.0
	Speed (2)	1.5
	Hyperlinks (2)	2.4
Nurse-physician communication	Openness (4)	2.7
	Accuracy (5)	2.4
	Understanding (8)	2.2
Safety culture	Teamwork (14)	2.8
Stewardship Climate	ASP-questions (4)	2.3

a. Mean scores are presented per scale. All individual items were scored on a 5-point Likert scale, with scores ranging from 0 (totally disagree), 1 (disagree), 2 (don't agree, don't disagree), 3 (agree), to 4 (totally agree)

With the questionnaire, we measured the following subdomains: Task support: 2 items, Reliability: 1 item, Persuasiveness: 3 items, Unobtrusiveness: 4 items, Relevance: 3 items, User friendliness: 3 items, Speed: 2 items, Hyperlinks: 2 items, Openness: 4 items, Accuracy: 5 items, Understanding: 8 items, Teamwork: 14 items, ASP: 4 items. Table 1 shows the accumulated, averaged scores of all participants on the scale. Negative items were conversed.

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Higher numbers means a more positive score on that domain (e.g., better communication, more persuasiveness of available information sources, etc.). Table 1 shows that although nurses experience the information they use to be supportive of their task, score of 3.0 (on a 0-4 scale), it is not easy or user friendly to find information, given the low scores on unobtrusiveness (1.9), speed (1.5) and user friendliness (2.0). Further, moderately lower scores are found on accuracy (2.4), understanding (2.2) and stewardship (2.3).

B. *Scenario tests*

The reported results are preliminary (see Future Work for planned analyses)

Sixteen nurses were presented with three scenario's each. Nurses needed different amounts of time to resolve the scenario's, ranging from instantly resolving it (ready knowledge), to up to 8 minutes needed to find the information. To complete the scenario's, nurses used the following strategies: read drug instruction leaflet, search pharmacy information website, search on national pharmacologic information site, search protocol database, search in (outdated) print instruction manual, call physician, call pharmacist, ask a colleague, search in Google, and in some cases, the nurse had sufficient (ready) knowledge to solve the scenario.

Among the experienced problems when resolving the scenarios are: difficulty to decide on the correct source to search in, difficulty to access a source (including technical problems/long page loading time/login problems), difficulty to localize and comprehend the precise information needed (re-reading large amounts of text), and more in general, time needed to find the information.

C. *Log file analysis*

Intended use is somewhat difficult to establish. First of all, nurses indicated during development phases that they especially look for instructions when dealing with antibiotics that are unfamiliar to them and this does not happen frequently (otherwise, they would quickly become familiar with the antibiotic and the related information). Further, information is needed when a patient reacts to the medication in an unexpected way (side effect or allergy). Lastly, inexperienced nurses may need to look up information more often than experienced nurses. Thus, information need instances do not arise regularly and are difficult to predict, but when they arise finding correct information fast is important. The application was launched at the end of March 2013, and has been used four times per day on average since. The bounce percentage is 8% (users leaving directly after entering). The log files show a steady use of the application (see Figure 3). Pages that are viewed most, aside from the welcome page and antibiotic overview pages (see an example page in Figure 1), include instructions on preparation and instructions on administration. Information on the antibiotics Amoxicillin-Clavulanic acid and Ceftazidim was viewed most often. The first is used frequently, but the second is used much less on these wards. The users prefer to search for an antibiotic by typing it in the search field; 74% vs. 26% out of 3,060 search instances.

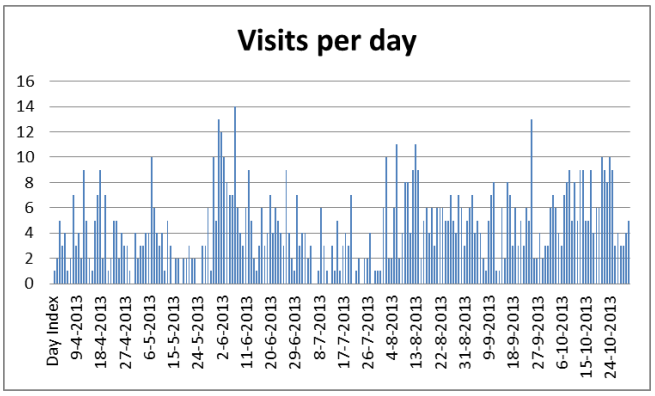

Figure 3. Daily app visits throughout the pilot period.

V. DISCUSSION

A. *Effects on work process*

During development, nurses already proclaimed that having all their information centralized to one location is helpful. However, with the explosion of available medical apps, information systems and other information sources, providing more information is not always better [21]. This is supported by the baseline questionnaire that measured several aspects of information seeking behavior and appraisal. It shows that although nurses show they have good information, it is not user friendly and costs time to find. The scenario-based tests show similar results; nurses loose time locating the desired information. So, information quality is not a problem, finding the right information quickly is. This problem might be overcome with the app, as we hypothesize, because it tailors information and provides chunks that match the information need.

Centralized, tailored information possibly helps to empower nurses in order to function optimally in antibiotic stewardship. Tailored information is one of the areas where the questionnaire and scenario tests results show room for improvement, as well as stewardship culture. For nurses to be able and feel confident to detect and discuss sub-optimal antibiotic use, they need to be able to rely on quickly available information. However, organization safety culture and nurse physician interaction play a big role and need to be addressed as well. Possibly, standardized communication aided with alerts and checklists of when to alarm or discuss with a physician can be useful [22].

B. *App use*

The log file analysis shows that the app does support nurses during their work: use remains steady over time, and the bounce percentage is low. As original sources of information are still available to the nurses, the data show that at least some nurses prefer to use the app instead of conventional materials, as they keep accessing the app,

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months after its release. Relatively little introductory activities were undertaken; some nurses attended an instructional meeting and fact sheets on antibiotic stewardship and the app were distributed. The minimal introduction may have sufficed because the intended users initially proclaimed they liked the concept and look and feel of the app, which has possibly led to increased willingness to start to use the app, and spread the word. It makes a strong case for human centered design, as involvement in the development process generates user commitment. It might be more difficult to reach this type of involvement on a large scale however.

As the most popular pages of the app are instructions on preparation and administration of antimicrobials, task support can be better. Of course, these pages are expected to be visited most frequently, because preparation and administration of antimicrobials are tasks that occur most often, whereas side effects or unexpected progress or deterioration in patient status occurs much less frequent. However, the app should provide support in these not-so-frequent occasions so in the app's evaluation, attention will be paid to precisely what content of the app is most useful to the nurses, and why other content is used less often.

C. 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 so automatically depends heavily on the information sources that underlie the app. In our case, 'filling' the app 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, 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 maintain information up to date.

With regard to implementation throughout the hospital, nurses outside our pilot ward found the app on the intranet of the hospital and wanted to use it. In this sense, the app implemented itself just by being available. In addition, physicians who the app was demonstrated to were interested in a physician-aimed version. To some extent, the positive reactions to the app can be explained by the fact that often medical information applications are developed and managed by experts. They offer an expert-based view and scope of information. 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. Human centered design can help to meet end-user needs [23]. However, when these needs require highly tailored information via applications with dynamic content that need of frequent quality checks and updates, this poses some challenges. Design teams should then find a balance between available resources to manage the information, and generalizability and up-scaling possibilities.

D. Limitations

The outcomes of this research must be interpreted with care because of several possible limitations. First of all, the application was developed and tested with the help of nurses of two wards in one hospital. Generalizing the results greatly depends on the specific information sources in place and the app'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 app are among such up-scaling activities.

Further, the questionnaire baseline measurements suffer from a substantial non-response (58%). Even though for survey research this might not be high, given the relatively small sample (64 nurses participated in the pilot) the results must be interpreted cautiously. However, with the scenario-based tests we were able to reproduce some of the questionnaire results regarding nurse experience of finding and using information; the scenario tests show, as well as the questionnaires that this is time-consuming and user-unfriendly.

Another point of caution lies in the operationalization of antibiotic stewardship work processes. To detect the effects of the app on work processes regarding antibiotic stewardship is difficult, especially in a short period. As nurses are not the actual prescribers, the effect of more knowledge and empowerment can only indirectly influence actual use. With the questionnaire we are able to detect some antimicrobial stewardship-related behaviors; e.g., whether nurses give physicians suggestions regarding antibiotic treatment, or alert physicians when treatment seems to be sub-optimal. Besides, we plan to study hospital statistics on antimicrobial use and length of stay to get an indication of possible effects on actual antibiotic use. Antibiotic therapy appropriateness and optimization (adjusting therapy timely based on patient progress) is determined on a per-patient basis [24], as it depends on every patient's unique status (in other words, what 'optimal' is, depends on patient-specific characteristics). Therefore, the effects of the app on antibiotic stewardship would be incomplete when looking at overall antibiotic use alone. So, depending on post-measurement results and the up scaling of the app, per-patient analysis will be done as well.

E. Future Work

In-depth analysis of the scenario-test recordings and transcripts will enable statistical comparisons between the three scenario research conditions: information search *without* app, before implementation; information search *with* app, after implementation; and information search *without* app, after implementation. The conditions will be compared on the following variables: time needed for search, number of encountered problems during search, number of times a scenarios was resolved correctly. Furthermore, scenario

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results regarding encountered problems as vocalized by the participants will be analyzed and grouped. As mentioned before, on a patient basis, changes in quality of care will also be studied using time series analysis on variables such as length of stay, antibiotic use, and mortality.

The application will be introduced on different wards and in other hospitals as well, following short re-design or adaptation of the app and its content to fit local work methods. This broad implementation will be accompanied by evaluations on use and user satisfaction.

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