Understanding eHealth use from a Persuasive System Design Perspective

An Antibiotic Information Application for Nurses

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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.**

Keywords-eHealth; antibiotic stewardship; nurse; task-support; log data; persuasive technology

I. 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.

A. 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][6][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].

B. 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].

C. 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).

D. 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.

II. 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 (tablet, smartphone) use. 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

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

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

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 Fig. 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 Fig. 1). Fig. 2 shows an instruction page of the AI Application, showing information on drug administration, including what to pay extra attention to. A demo version (in Dutch) of the AI Application can be accessed online via [19].

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 an 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 Fig. 1.

III. METHODS

A. *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.

B. *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.

C. *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.

D. 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.

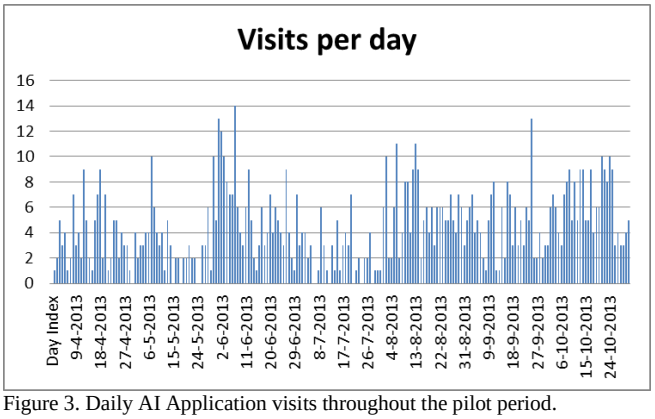

Figure 3. Daily AI Application visits throughout the pilot period.

IV. RESULTS

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

A. 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 Fig. 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 Fig. 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 Fig. 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 Fig. 1 for an example), are pages of the category task instructions (Fig. 1, section A): information on dosage, 189 page views (8.5%), instructions on preparation, 1,025 page

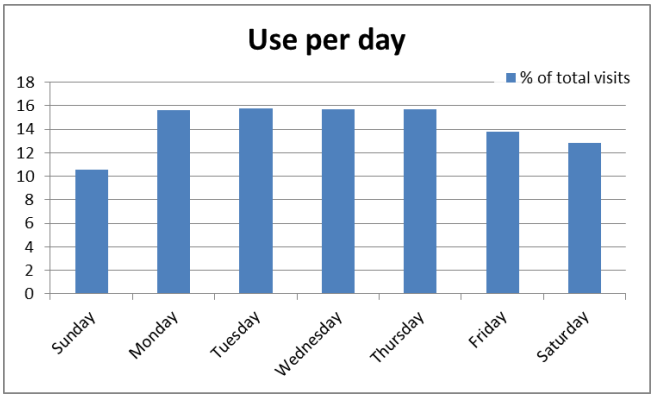

Figure 4. AI Application use per day of the week.

Figure 5. Hourly AI Application visits throughout the pilot period

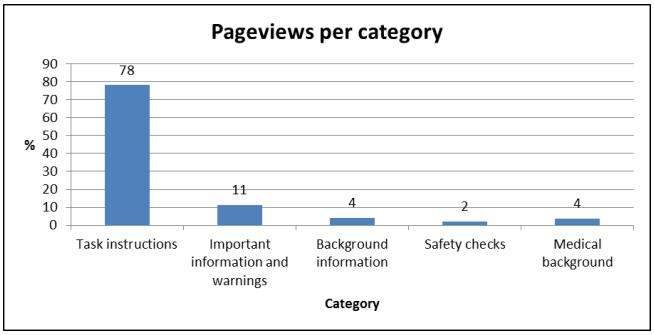

Figure 6. Page views in percentage per section.

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-Clavulanicacid, Ceftriaxon, and Ceftazidim was viewed most often with page views (including overview pages) of respectively 717 (16%), 609 (13%), and 537 (12%).

B. 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".*

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 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.]".*

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

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".*

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

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".*

V. DISCUSSION

A. AI 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].

B. 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, that show that the AI Application is used most often when concrete tasks of preparing and administrating 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].

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 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.

D. 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].

E. 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.

F. 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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