Understanding technology adoption in clinical care: Clinician adoption behavior of a point-of-care reminder system

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Summary
Background: Evaluation studies of clinical decision support systems (CDSS) have tended to focus on assessments of system quality and clinical performance in a laboratory setting. Relatively few studies have used field trials to determine if CDSS are likely to be used in routine clinical settings and whether reminders generated are likely to be acted upon by end-users. Moreover, such studies when performed tend not to identify distinct user groups, nor to classify user feedback.

Aim: To assess medical residents’ acceptance and adoption of a clinical reminder system for chronic disease and preventive care management and to use expressed preferences for system attributes and functionality as a basis for system re-engineering.

Design of study: Longitudinal, correlational study using a novel developmental trajectory analysis (DTA) statistical method, followed by a qualitative analysis based on user satisfaction surveys and field interviews.

Setting: An ambulatory primary care clinic of an urban teaching hospital offering comprehensive healthcare services. 41 medical residents used a CDSS over 10 months in their daily practice. Use of this system was strongly recommended but not mandatory.

Methods: A group-based, semi-parametric statistical modeling method to identify distinct groups, with distinct usage trajectories, followed by qualitative instruments of usability and satisfaction surveys and structured interviews to validate insights derived from usage trajectories.

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Results: Quantitative analysis delineates three types of user adoption behavior: ‘‘light’’, ‘‘moderate’’ and ‘‘heavy’’ usage. Qualitative analysis reveals that clinicians of distinct types tend to exhibit views of the system consistent with their demonstrated adoption behavior. Drawbacks in the design of the CDSS identified by users of all types (in different ways) motivate a redesign based on current physician workflows.

Conclusion: We conclude that this mixed methodology has considerable promise to provide new insights into system usability and adoption issues that may benefit clinical decision support systems as well as information systems more generally.

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1. Summary of research results

What was known before the study?
- Clinical decision support systems can enhance the clinical performance in a variety of areas.
- Many CDSS fail in real-life installations regardless of the technological quality of the application.
- Research on the effects of CDSS on user adoption and organization workflows in realistic settings is lacking.

What the study has added to the body of knowledge?
- Introduced a new statistical methodology drawn from the social sciences for analyzing revealed behavior versus perceived behavior in medical informatics evaluation studies.
- Illustrated its successful application in understanding the user adoption behavior and categorizing users into distinct user groups.
- Physician qualitative impressions of the CDSS are consistent with their classification according to the statistical clustering model for user adoption.
- A CDSS, especially designed for outpatient clinic practice, must incorporate workflows consistent with care processes during the physician–patient encounter.

2. Introduction

Clinical cueing systems (CCS) are a class of clinical decision support systems (CDSS) that send just-in-time alerts to clinicians when potential errors or deficiencies in the patient management are detected. Significant research evidence shows that CDSS can enhance the clinical performance in drug dosing, preventive care, and other aspects of medical care [1–9]. However, most evaluations of CDSS emphasize clinical performance and diagnostic accuracy; few studies address user acceptance and adoption of such tools in the ambulatory care practice setting that reflects specific characteristics of the users and/or the environment [8,9]. It remains unclear whether a CDSS shown to be effective in laboratory settings will be effective over time in routine clinical settings with real patients.

Despite efforts to optimize CDSS as much as technically possible, practitioners may not view use of a CDSS as being beneficial, and thus may be reluctant to incorporate it into their daily practice [10]. A previous study estimates that 45% of computerized medical information systems fail because of user resistance, even though these systems are technically sound [12]. A variety of factors can contribute to this resistance, such as insufficient computer ability, diminished professional autonomy, lack of awareness of long-term benefits of system use, and lack of desire to change conventional behaviors. As systematic reviews have indicated, few evaluation studies have considered these attitudinal and contextual factors of system acceptance and adoption, and little use has been made of qualitative techniques in studying effectiveness of CDSS, leaving unanswered questions, such as why some systems worked while some others failed. Researchers, therefore, have called for methodological pluralism for evaluating informatics applications [8,9,10].

With these perspectives in mind, we have developed and deployed a CDSS called clinical reminder system (CRS) for chronic disease and preventive care management using evidence-based medicine principles for an outpatient primary care clinic of an urban teaching hospital. Our primary objectives in the long-term study include evaluation of adoption and diffusion of information technology interventions at the point-of-care, and impacts on patient and organizational outcomes. In this paper we assess clinicians’ acceptance and adoption of the clinical reminder system using mixed methods: a quantitative analysis identifying distinctive developmental trajectories of user acceptance and adoption of the system over time, and a qualitative examination of the attitudinal and contextual influences on adoption of the system, providing insights into interpreting the adoption trajectories generated by specialized models.
3. Methods

3.1. Clinical reminder system

Clinical reminder system (CRS) uses patients’ medical status data to provide “just-in-time” reminders to clinicians at the point of care consistent with the latest evidence-based medicine guidelines for chronic disease and preventive care management. CRS is made available to physicians and clinic staff via desktop computers installed in every examination room of the clinic. The application integrates the hospital’s administrative, laboratory, and clinical records systems into a single database. Patient’s data essential to specific guidelines, but not stored in the database, are collected and entered into the system by clinic staff and physicians during the encounter.

CRS is adapted to the workflow of a typical clinic by supporting the appointment scheduling, patient check-in, recording of vital signs, browsing patient information, generating physician-directed reminders, and check-out activities. Reminders generated by CRS take the form of on-screen recommendations to have tests scheduled or performed, review abnormal test results, receive vaccinations, or follow-up on patients with medical conditions that require unscheduled interventions. CRS is currently designed to improve the quality of care for two chronic diseases: diabetes and hyperlipidemia, and five preventive care categories: steroid-induced osteoporosis, influenza, pneumonia, breast cancer, and cervical cancer. Details of the architecture of CRS and the algorithms that implement evidence-based medicine guidelines are presented elsewhere [13].

The data used in this study are the combinations of quantitative data from log files of actual usage of CRS, results of a statistical trajectory analysis method, and qualitative data from surveys, field interviews and textual notes (detailed below). We analyze these data using a combination of methods, i.e. statistical models to identify user groups and qualitative analysis methods to understand usage patterns in the context of defined user groups. This was done not only to understand who the users are, and how and why they do or do not use the system, but also to define high-priority areas for system redesign and deployment based on actual user feedback.

3.2. Intervention and quantitative usage data collection

CRS was installed in the hospital’s primary care clinic, which serves as a rotation-site for first-, second- and third-year residents. System implementation was completed 3 months prior to the study, and individual training was provided to all the users. The adoption study was conducted between 1 February and 30 November 2002. Forty-one internal medicine residents used the system to treat, approximately, 4500 patients. Their usage data, from system login to logout (which patient records were accessed, what data was entered, whether reminders were generated, what actions were taken on various reminders, and so on), were recorded for each user in the log files. Results of system use in this clinic setting provided the data for usage analysis that forms the basis of further qualitative assessments.

3.3. Qualitative data collection from multiple sources

We conducted structured interviews with 16 residents who used the system continuously during the 10-month evaluation period. Based on initial usage analysis indicating three distinct user adoption groups, we enrolled users from each of the usage groups to ensure representation of the clinician groups who demonstrated all types of adoption behavior. Choice of participants was based on the clinician’s availability.

We also administered two surveys to assess the system usability and user satisfaction, respectively. The two survey instruments are based on IBM satisfaction questionnaire, developed by Lewis [14]. The survey response rates were 78% for both (25 out of 32 and 29 out of 37, respectively). The user satisfaction survey, conducted at the end of the 10-month evaluation period, included a number of open-ended questions for residents to express their views, experiences, and expectations of the system. This feedback was compared to the themes that emerged from the interviews to check on the consistency of the qualitative assessments.

The qualitative data from interviews and surveys were analyzed by the authors using the constant comparative method—an inductive method that “involves the continuous comparison of incidents and interviewees’ remarks, and then constructs categories and themes from the data” [15]. Finally, we compared the themes we identified against the user types generated using a specialized statistical method (described below) to identify the discrepancies among the user adoption groups. We reported these results to administrators and preceptors of the clinic to verify the findings, as well as to solicit their interpretations and comments based on their experiences.
In addition to the data collected via surveys and interviews, we analyzed electronically filed bug reports and the text notes, stored by the system in conjunction with reminder responses, as well as other types of data entry. We also made a number of random on-site observations to determine how clinicians actually used the reminder system and how their patient interactions were affected by the system. These assessments are incorporated in our qualitative analysis.

3.4. Developmental trajectory analysis

A “developmental trajectory” describes the course of a developmental behavior over age or time. Developmental trajectory analysis (DTA) is a semi-parametric, group-based approach for identifying distinctive groups of individual trajectories within the population, and for profiling the characteristics of group members [16,17]. Given the observations of users in discrete time periods, and well-defined user characteristics, DTA maximizes a Bayesian information criterion, by which users can be assigned to distinct groups following distinct trajectories. This method optimally determines the number and membership of groups. DTA has been successfully applied in many areas, such as studies of physical aggression among the youth [17]. A detailed description of this model can be found in [18].

Our approach to this study can be summarized in Fig. 1.

4. Results

4.1. Distinct user adoption groups

Our application of DTA identified three distinct user adoption types. The developmental trajectories and the group compositions are depicted in Fig. 2. Solid and dashed lines denote the observed and predicted trends, respectively. Observed data values are computed as the mean use rate of users assigned to each of these groups identified by estimation. Predicted values are computed using DTA model coefficient estimates. Numbers above each trendline denote the percentage of residents that demonstrated coherent behavior consistent with that trend.

Fig. 2 also reveals distinct trends in adoption patterns. Clinicians later confirmed that these trends reflect actual experiences of system use. For instance, residents classified as “light” (41.46%) initially used the system for about 35% of all patient encounters, and this rate remained steady over the 10-month evaluation period. “Moderate” users (36.59%) had the highest initial usage rate, about 70%, but this rate consistently decreased over the study period to a level comparable with that of the “light” users. “Heavy” users (21.95%) had an initial usage rate of about 50%, which increased consistently to almost 100%.

Based on actual usage data, we found that “light” users tended to limit their interaction with the system to accessing patient records, entering
minimal new patient care data and rarely reviewing and responding to system-generated reminders. "Medium" users tended to enter more patient care data and generated a higher volume of more-relevant reminders, but not to act on them consistently. "Heavy" users generally used all the system functionality, as intended for nearly all patient encounters (exceptions are described below). They also often added comments that assisted in follow-up care. Additional details regarding usage-based user acceptance and adoption analysis are provided elsewhere [18].

4.2. Qualitative assessments via surveys and interviews

"Clinicians" comments on the reminder system are grouped according to the generally positive or negative nature of the feedback, and presented in decreasing order of consensus among respondents.

4.2.1. Positive feedback

Most of the positive feedback is grouped under the theme of "practice implications". These comments suggested that CRS had positive implications for the medical practice. Typical comments include: "It does move me to think about some preventive measurements" and "Hard to miss things we usually tend to". These comments are indicative of a general consensus among residents that use of this reminder system has the potential to improve clinician performance, leading to better quality of care. The other major category of positive feedback is "ease of use"; typical comments such as "Easy to use, time efficient" suggest that use of the system required very minimal training and skills. Difficulty of use or lack of computer proficiency appears not to be a significant barrier for incorporating the system into their routine practice.

4.2.2. Negative feedback

Most of negative feedback is grouped under the theme of "iterative advisories", criticizing the relevancy of reminders issued for follow-up visits. Typical comments include: "It does not take feedback from us" and "It generates the same reminders every time". The textual notes that accompanied reminder responses also provide evidence regarding the potential lack of relevance of the reminders; nearly 30% of such notes asserted "the suggested action has already been taken but not yet recorded".

The theme of "heavy and hard data entry duty" relates to the considerable amount of time and effort required for entering the patient data. Comments that support this conclusion include, for instance: "It is very tedious to put in all of the work", "takes too much time to enter patient". Technical difficulties such as lack of typing skills have proven to be irrelevant, based on observations made on-site and confirmed by the interviewees. Residents were also reluctant to perform the data entry duty that is considered a traditional role of support personnel. One user commented: "I think nurses should enter it. I don't have time in an appointment of 20 min to fill all reports".

Another major type of negative feedback is grouped under the theme of "soliciting for one single integrated system", reflecting the residents' desire to have a single system perform all encounter-related tasks. One example of comments in this connection is: "we should only have one complete system with labs/meds/notes, etc.". Clinicians expressed concerns about time and efficiency impacts in another set of negative comments. This theme is distinguished from the data entry issue because it specifically targets the reminder generation process. Examples of comments supportive of this theme include: "takes too much time to review reminders" and "responding to reminders can cut in on our time with patients". Further investigation revealed that comments grouped under this theme originated primarily from residents classified as "light" or "moderate" users. In contrast, this theme did not emerge from feedback of the "heavy" users who used the system frequently and worked to integrate system-generated reminders into their practice. A qualitative analysis based on recorded usage logs indicate that light and moderate user groups spent, approximately, 18.5s on average on reviewing and responding to the reminders, whereas the heavy user group spent 37.1s.

Some physicians also believed that CRS disrupted physician–patient communication. Typical comments in this vein include: "using the system is disruptive during patient encounters". To help researchers learn how the reminder system was actually being used, we conducted on-site observations of a number of randomly selected patient encounters. Observational descriptions reveal that use of the system during encounter did, in fact, impede physician–patient communication to some extent. For instance, residents repeatedly turned back and forth between the computer and their patient. Although most of the interviewees agreed that patients did not object to the presence of the computer, some residents did express concerns that quality of physician–patient communication could be diminished.
As was the case for the “time-consuming and detrimental to efficiency” theme, this feedback primarily originated from the users of light or moderate user groups. We conclude, this is due to the same fact that “heavy” users had adapted their behavior accordingly. We will discuss this modified behavior in the later section.

Finally, residents complained that the reminder system lacks guidance in the application of workflow. In contrast to the history and physical examination forms that residents typically use, the interface of CRS appeared to provide little guidance as to a preferred order of data entry.

4.2.3. Discrepancy among user adoption groups
Discrepancies among user adoption groups are clarified by performing the constant comparative method within groups. Perspectives found to be distinct across groups include the themes of “time-consuming and detrimental to efficiency” and “disruptive to physician—patient communication”.

The fact that “heavy” users did not comment negatively on these two themes is noteworthy; we find that these users had adapted their behavior to use the system and act upon reminders at the end of encounters, or even after patients left. We do not favor such a modification to the intended system use because it is contrary to the rationale of reminding clinicians at the point-of-care to improve compliance with evidence-based guidelines. However, we view this behavior as an indication of these users’ strong desire to use the system. In contrast, “light” and “moderate” users lacked such initiative, and thus gave up use of the system before any further adaptation attempts. These results are consistent with the patterns observed in the trajectories that we depicted from usage data by DTA analysis; although “moderate” users initially showed even stronger enthusiasm than “heavy” users, their usage level underwent a gradual decline, and the usage of “light” users remained at a constant and very low level.

5. Discussion
5.1. Methods
The mixed methods model we have used in this paper has enabled us to successfully distinguish distinct groups of CRS users, to validate the results of statistical analysis with actual user comments, and to finally identify key user concerns that have enabled system redesign towards more efficient and more effective use.

5.2. Results
Comments and related system data related to iterative advisories indicate that information gathering and reminder-generating functions of the system, particularly in situations that involve multiple encounters, are problematic. We have investigated this problem in great detail with respect to the system’s fundamental architecture, coding integrity, system integration, and user practices. We conclude that the problem has its origin in the “heavy and hard data entry duty” issue. Due to the effort required for data entry, we observed that clinicians tend to avoid entering newly received patient information that is essential for the reminder algorithms to work, which in turn affects the relevance of reminders the system generates.

For physicians who desire a single integrated system, the lack of a comprehensive electronic medical record system incorporating physician order entry undoubtedly created ambiguity regarding the search for and recording of relevant clinical data. It also challenged the initial perception of system designers that the reminder component could be treated as an “add-on” to the clinicians’ traditional workflow.

Regarding comments on the use of CRS being time-consuming and detrimental to efficiency, we observe that our CDSS was intended to replace the traditional hand-written case notes. Despite the fact that hand-written notes are often hard to read and search and are bulky, many users believed that the CDSS decreased the efficiency of the patient encounter. We think that this particular problem may be exaggerated due to the pre-existing perceptions held by “light” or “moderate” users that use of such systems would severely slow the things down, or amenable to straightforward solutions such as modifications to practice routines that accommodate the presence of reminders.

The comments on CRS’ unguided application workflow have resulted in a number of re-engineering requirements. The CRS client application is currently coded in Visual Basics, as a standard Microsoft Windows application. The user interface is composed of several tabs that lead to different functionality areas. These tabs, labeled “current reminders”, “visit details”, “lab test”, “diagnosis” and so on, did not provide physicians with the specific guidance as to the order of data management; data to be reviewed prior to the encounter, data to enter during the encounter before generating reminders, data to be entered in response to reminders generated, and encounter summary forms to be printed for the patient chart and for patient check-out.
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5.3. Comparison with existing literature
In the absence of systems that are deployed and regularly used in the field, researchers tend to use user perception as a means of studying technology acceptance and adoption. For instance, a widely accepted method in IS research, the technology acceptance model (TAM), relates perceived usefulness to use [21]. However, as other studies suggest, perceived usefulness is poorly correlated with actual use. In addition to this, self-reported usage, or intent to use, may not be an appropriate surrogate for actual use because users are poor estimators of aspects of their own behaviors [20].

Users of an IT application differ in many ways. It has been well recognized that individual users play a crucial role in that their experiences, and their opinions or reactions to a technology make a difference in whether or not the technology will be adopted [19]. Nevertheless, few studies have used individual-level data to measure the magnitude of user differentiation, and the impact of such differentiation on technology adoption. Furthermore, voluntary use has not been adequately addressed in the existing informatics evaluation studies due to the prevalent experimental designs, while the level of voluntary adoption has received close attention in evaluation studies in other disciplines for its value in assessing IT impacts [11,12].

5.4. Lessons learned
Resistance exists to use of the reminder system. Although there is general consensus among clinicians that use of this system can potentially enhance the clinical performance, leading to improved quality of care, a significant proportion of users remained reluctant to incorporate the system into their daily practice.

One explanation for the low usage of the reminder system is that the clinicians primarily viewed the use of reminders as an "add-on" to their work instead of an intrinsic part of the patient encounter. Use of the system and the effort they need to commit to activities such as data entry were viewed as a cumbersome addition to their traditional patterns of care delivery.

Different users responded to this perceived threat in different ways; some rejected to use the system after very minimal attempts, and some adapted their practice routines in a way that enabled them to use the system, though not always in a manner consistent with the system's principle of generating reminders and storing physician responses to these reminders at the point-of-care. Pre-existing perceptions are found to have significant impacts on the system adoption. "Light" users, for instance, stayed away from the system from a very early stage.

5.5. Implications for re-engineering the reminder system
The studied system implementation clearly did not meet the goals of the designers regarding system use. However, our experiences with this process have helped us re-engineer the reminder system in a number of specific ways.

In response to the "iterative advisories" theme, we have redesigned the reminder generation mechanism to ensure that a reminder generated repetitively due to lack of feedback information is rephrased or temporarily suppressed. This is not a permanent or comprehensive solution; we assumed that the data entry policy would be rigorously followed, ensuring that records of actions would be fed back to the system in a timely manner. Solving this problem more permanently requires a more seamlessly integrated system and more pertinent resident education of the importance of the data entry.

Tediousness of recording data and ambiguity of ownership of the data entry duty impose a severe threat to the implementation of systems such as CRS. We have observed that certain clinical data are not captured at all by CRS due to a lack of system functionality. In response to discussions with administrators and preceptors of the clinic, we have redesigned CRS to incorporate the clinical history and physical examination forms that were previously kept in paper form. We expect that this will enable the residents to enter a wide variety of relevant clinical data electronically. Such effort also fulfils the desire of users to have a single system to accommodate all the clinical tasks.

To further encourage the users to generate and respond to reminders, the new system also merges evidence-based reminders into the encounter process via history and physical examination forms. Reminders currently appear primarily in the order entry section in the form of "recommended orders"; others appear in the history or physical examination forms so they can receive attention while physicians perform other routine tasks.

The presence of computers in examining rooms is found to be a distraction to efficient physician–patient interaction. Although this problem is not specific to the reminder system, we recommend that examination rooms be reconfigured to better accommodate the system, for example by placing computers in such a way that clinicians can view the monitor while preserving eye contact.
with patients. Longer-term technological solutions include delivery of reminders via tablet PC or handheld devices; such considerations are beyond the current scope of this project, however.

The traditional Windows-based user interface composed of hierarchical “forms” and parallel “tabs” does not provide adequate guidance for users’ workflow. To remedy this problem we have converted the system into a fully web-based application that largely resembles the paper-based forms familiar to users. An intuitive navigation tool now indicates the appropriate steps of workflow. This platform transition also makes possible remote access of patient data via the web and redirecting reminders to other devices, such as personal digital assistants. Nevertheless, it will be crucial to train physicians in the appropriate use of information technology in the examination room.

6. Conclusion

In this study, we assess clinician users’ acceptance and adoption of a clinical reminder system. We apply a mixed methods approach that combines quantitative methods to identify distinct developmental trajectories of user adoption with qualitative instruments to examine the causal processes of such adoption behaviors.

We find that a significant level of resistance exists to the use of the reminder system; a large proportion of users demonstrated a consistently low or decreasing level of usage over time. Even those users who were labeled as “heavy” had adapted their behavior to use the system posterior to the patient encounter; though such alteration is indicative of their desire to use the system, it violated the principle of improving compliance to evidence-based guidelines at the point-of-care.

The lessons learned and experiences gained have helped system designers to re-engineer the reminder system for future implementation. We also conclude that this mixed approach of quantitative and qualitative methods has considerable promise to provide new insights into the system usability and adoption issues that may benefit clinical decision support systems as well as information systems and adoption issues that may benefit clinical decision support systems as well as information systems and qualitative methods has considerable promise.

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