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Developing a User-centered Voluntary Medical Incident Reporting System

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Abstract

Medical errors are one of leading causes of death among adults in the United States[1]. According to the Institute of Medicine, reporting of medical incidents could be a cornerstone to learn from errors and to improve patient safety, if incident data are collected in a properly structured format which is useful for the detection of patterns, discovery of underlying factors, and generation of solutions. Globally, a number of medical incident reporting systems were deployed for collecting observable incident data in care delivery organizations (CDO) over the past several years. However, few researches delved into design of user-centered reporting system for improving completeness and accuracy of medical incident collection, let alone design models created for other institutes to follow. In this paper, we introduce the problems identified in a current using voluntary reporting system and our effort is being made towards complete, accurate and useful user-centered new reporting system through a usability engineering process

Keywords:

Patient Safety, Incident Reporting, Usability, Task analysis, heuristic evaluation

Introduction

The University of Missouri Health System has implemented a web-based medical incident reporting system called Patient Safety Network (PSN) since 2002. In the previous study [2] on one year dataset of medical incidents, 2,919 cases out of total 5,654 reports were finally extracted as non-duplicated and valid data after cross checking consistency and completeness. Among them, 958 cases (32.8%) were labeled with "miscellaneous", which was too blurry to be analyzed in-depth even after laborious manual data pre-processing. In addition, the rest of dataset still face challenges due to chunks of descriptive incident data in free text format.

The completeness and accuracy of reported incidents are core attributes for meaningful use and iterative improvement of voluntary medical incident reporting system. According to the previous researches, plenty of conceptual blurs were existed in the process of medical incident reporting. For example, how to break down the "miscellaneous" dataset into distinct subclass; how to build a comprehensive hierarchy to precisely express incident classes such as "fall", "medication/IVs"; how to approach a rating scale system of harm score for reporter to evaluate incident severity with less uncertainty; and how to improve reporting process for meaningful description of medical incidents. These are the questions asking for higher quality of data entry. On the other hand, system utilityb[3] perceived by levels of users could either accelerate or impede the enhancement of such application, which depends on system feedback. For instance, the comprehensive summary and analysis results of incident data generated by system is a foundation to develop collaboration for system using among the stakeholders such as reporters, analyzers (designer) and CDO leadership. That feedback cycle could effectively and efficiently assist designers in interpreting and working out the problems that arise during use, and in return, different level of users can quickly perceive improvement in person. Consequently, a sustained development process of user-centered voluntary medical incident reporting system could be established. However, all supposed achievements above heavily rely on quality data.

For this purpose, we are redesigning a voluntary medical incident reporting system with user-centered concerns. In contrast, the current PSN system has a variety of usability weakness and heuristic violations in aspects of site structure, navigation, scanability and flexibility, according to Nielsen's guide book[4] for web design. Therefore, usability is regarded as a standing point of user-centered reporting system design at the initial stage of our study.

Previously, usability was proved as one of most influential human factorsb[5] to usefulness and ease of use in this kind of system. From recent published literatures [6-7], it comes to the fore that the ultimate accept or reject of such system largely relies on the degree of system usability [8]. By far, due to time pressure and immature theories of engineering method, the usability studies were rarely conducted in the process of existed medical incident reporting system design and development system. However, it is believed that the usability issues are included from the beginning of the development process not only the iterative design cycle may shorten, more importantly new insights might be acquired on general system design aspects that might potentially lead to errors in healthcare. So in the entire project, we combine usability engineering as an initial part of development cycle for a user-centered medical incident reporting system.

Methods

The user-centered design framework [9] requires analysis at the user, task, function and representation level for effective design and evaluation of an information system. In a prototyping process, we started with a dominant type of users (nurse)

and employed a horizontal dimension prototyping method [3] to keep the features yet eliminate the depth of functionality.

Focusing on the functionality of reporting, firstly we conducted a task analysis inspecting the PSN interface to measure several fixed factors that might influence usage of system and set a series of goals for improving identified weakness. Secondly, we developed a new web-based interface using JavaScript, PHP and ExtJS library with new features on technology and content management such as Ajax and procedure based question-answer. And then executing task analysis again on the new interface aimed to confirm achievements of new design. Meanwhile, we conducted a heuristic evaluation to identify severe usability violations and use the results to improve the overall user-friendliness.

Task analysis

Referring to Nielsen's book of usability engineering [3], a task analysis is to study how users approach the task, their information requirements and how they deal with exceptional circumstance, identify points where users fail to achieve goals, spend excessive time, or feel uncomfortable. The analysis generates a list of all the information users will need to achieve goals, the steps that need to be performed and the criteria used to determine the quality and acceptance of results. In this case, we set three variables as inspected objects: mouse click, key stroke and memory load. By emulating a typical user's operation in reporting a patient fall incident, the step counting on these three aspects were summarized and grouped into four sections: initial questions, event common questions, event details and summary & others, as it shown in Table 1. The improvement of system on such concerns is believed to visibly reduce the operational and mnemonic workload in the process of incident reporting. What make these three factors interest us is they can be measurable and improvable by interface re-engineering.

Concretely, we went through the PSN and new interface with the same scenario of patient fall, which requires largest number of questions in all existed eight types of event. They are including blood/blood products, skin impairment, medication reaction, equipment/device, medication/IVs, fall, procedure/treatment and miscellaneous. The number of mouse click and free text input was calculated and summarized for same steps of each interface. Simultaneously, the analysis of memory requirements was conducted for each section (a granularity defined above) of two designs to measure memory requirements of reporting system questions. In the end, all summarized outcomes on mouse click, key stroke and memory load were listed into a tabular format for comparing differences of two systems. This spreadsheet can intuitively illustrate the progress in usability issues between the two interfaces.

Heuristic Evaluation

Heuristic evaluation is a usability inspection method effective in uncovering design problems, which is considered to yield the most serious problems with the least amount of effort [10]. For this discount evaluation method, 3-5 usability experts are recruited to inspect interface design problems, and then they are requested to summarize and report heuristic violations as a basis for usability improving.

For resource limitations in terms of time and finance, we eventually enrolled three doctoral students majored in computer science with proper training on heuristic evaluation method. They were asked to use the 14 usability heuristics developed by Zhang et al. [11]. The 14 categories refer to: Consistency; Visibility; Match; Minimalist; Memory; Feedback; Flexibility; Message; Error; Closure; Undo; Language; Control; Document.

Table 1-The requirements at the Key Stroke, Mouse Click and Memory Load level of two interfaces

Sec	Task		PSN(A) Prototype(B) Both(S)	Key stroke	Click	Memory Load
Answer Initial Questions	Anonymous Report	A	RadioGroup check(Y/N)		1	Recall the title of health profession, facilities where incidents occurred and level of patient involvement
		B	Checkbox(default:uncheck)		0~1	
	Health Profession	A	Pulldown list		2	
		B	Has default value, auto-complete entry	Initial letters	0/2	
	Involvement	S	RadioGroup for facility and patient involvement		2	
Event Common Questions	Demographic	S	Name,Birthday and Gender	Patient name entry	10~11	Patient ID or name; When the incident happened and what date is that day; patient home unit and related doctors
	Event Date	A	Time pickup widge		2~3	
		B	Add with default value, two shortcut buttons		0~3	
	Address & clincians	A	pulldown list,text field		7	
		B	Add with auto-complete	Initial letters	7	
Event Details	Type & Harm Score	S	Both are RadioGroup check widgets		2	Recall entire process of incident and compare them with page quesitons in mind, then make a precise or
	A series of questions to depict cases,e.g."fall"	A	Single & Multiple textfields, RadioGroup, Checkbox, Dropdown list	up to 6,000 free text input	6+	
		B	Procedure based question-answering radio groups	Specify in short for unlisted items	4~11+	
Summary Other	Review info; save,submit, delete	A	Review but cannot modify info		1	memorize which question and which page this question is in
		B	Can modify most of info		1	
	Page flips	A	Button for backing to previous page		9	
		B	Navigational bar takes page flips		9	
Total		A		very much	42~44+	
		B		a few	35~49+	

Three experts were asked to conduct an on-site evaluation as a group. The entire process took about 60 minutes. The first 15 minutes were spent to explain background of evaluation, hand out an evaluation stepwise description and make a brief demonstration of interface operating. Then the experts did the evaluation as a group but individually, due to the timely evaluation for the first version of prototype. One of them played the interface as an incident reporter according to stepwise task description. At the meantime, the rest observed operations and inspected system features and feedbacks. They were asked to go through the interface together several times with following 14 usability principles (14 usability heuristics) and developed pertinent discussions. The group of evaluators jotted down usability violations and solutions suggested, and then rated a severity score for each usability violation based on the following scale:

- 0 - Not a usability problem at all;
- 1 - Cosmetic problem, need not be fixed unless extra time is available on the project;
- 2 - Minor usability problem, low priority to fix;
- 3 - Major usability problem, important to fix, so should be given high priority; and
- 4 - Usability catastrophe, imperative to fix before product can be released.

In the end, such results organized in Excel format were sent back to us as a feedback. The entire process was audio-taped and later reviewed several times to find out missing parts and remove duplicates (same meaning in different expressions). All of our modifications were emailed back to each evaluator for verification purposes.

Results

As a result of task analysis, Table 1 exhibits the detailed combination of two analyses. It manifests the interface testing outcomes in terms of mouse click, keyboard stroke and the retrieval of mnemonic information. The four sections of tasks were investigated, including initial questions, event common questions, event details and summary/other. The number of mouse clicks varys, which depends on if default value applies or not (e.g. 0/2 means that selecting "Health Profession" require 0 or 2 mouse clicks) and if a question has multiple values (e.g. 4~11+ means that depicting a fall event requires 4 to 11 plus mouse clicks to answer questions in format of radio button and checkbox). The column of key stroke argues the reasons of text inputting for each interface. And the last column elaborates the requirements of mnemonic data to each section. In total, the new design has a large range of mouse click counting number, 35~49+ clicks based upon a typical case used for testing; whereas, the PSN has 42~44+ clicks. But for requirements of key stroke and memory load, the new design requires much lower.

The changes above came with the following technical progresses we made in the new interface.

- Set default values with statistical evidences. E.g. our analysis shows nearly 70% of reporters are residential nurse and nearly70% medical incidents were reported within two days after occurrence. Therefore, setting "RN" as default value and creating two shortcut buttons for picking up today's date and yesterday can facilitate data entering.
- Present accurate and meaningful prompts at the appropriate position. E.g. replace a chunk of static instructions with over-the-cursor button tips and show concrete date on today's date button
- Shortcuts for data entry and adjustment. E.g. easy page flips, can edit almost all entered data at summary page
- Using closed-ended questions to substitute open-ended ones.
- Procedure based ("if-then" rules) process combined with closed-ended questions for collecting event details. Using standardized multiple choice questions to substitute open-ended questions in formats of multi-lines text field, single-line text field, checkbox, etc.

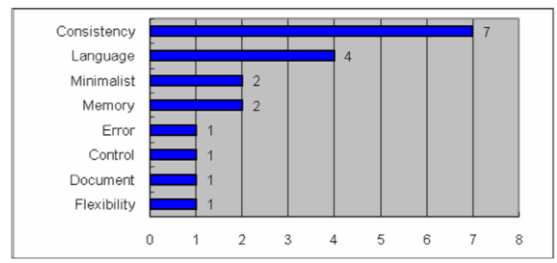

Figure 1-The categorical distribution of identified 19 usability violations

By heuristic evaluation, 19 usability violations were identified, which belong to 8 heuristic categories. Consistency and Language were the two heuristics most frequently violated in the new user interface. These two categories alone accounted for nearly 60% (11/19) of all the identified usability violations. The specific distribution of heuristics violated in this step is presented in Figure 1.

The concrete descriptions of result were organized into a tabular spreadsheet, which is a list of 19 usability problems found through the interface as well as hints for features to support successful user strategies. There are total six sections, including five sections of date reporting (initial info, event common info, event details, summary and harm score), as well as one section for general problems. The severity scores rated by three evaluators are averaged and the narrative texts are reorganized into proper categories. The Table 2 is an excerpt from all identified violations with severity score over 2.5 (major and catastrophic violations). In this table, the sections are consistent with them in Table 1.

Discussion

This study demonstrated the initial employed strategy for usability engineering a voluntary medical incident reporting system. First of all, the two dimensions of prototyping methods were introduced to decompose the entire system development into vertical and horizontal levels. Then, at the vertical level, we did research on reporting functionality of the current PSN and new interface to discover variables influencing usage of system through task analysis.

Table 2-An excerpt from major and catastrophic usability violations

Sec.		Problem Ddescription (P) Recommended Solution (S)	Heuristics Violations	Severity Rating
Initial Questions	P	No explanation to red asterisks for required questions	Document	4
	S	Explain at the first place where red asterisks appeared		
	P	Layout of two radio group widgets	Consistency	2.66
	S	Indent the options of these two widgets, use shaded block to highlight them		
Event Details	P	The name of button which triggers a reset of start over the event details question	Language	3
	S	Change button text ""restart"" changes into ""reload this page"" or ""clear""		
	P	Use "check one" to be a alert for radio group that only can check one option	Minimalist	3
	S	Remove "check one"		
	P	User is maypossible to forget to rate for event harm score	Consistency	3
	S	A better reminder or put it event harm score section into one a separate page to instead of on the navigational bar		

And at the horizontal level, we started a heuristic evaluation on the new interface with improved factors mentioned above. Such an iterative analysis, development and evaluation process will be continuing until all issues such as user types, tasks, functionality and data representation are completed at the both vertical and horizontal levels. This is our usability engineering method for system prototyping.

There are two reasons for us to follow the PSN system and develop the new system framework and data entry process. One is because some of changes made to solve certain problems may cause new problems. Another reason is about learnability. A substantial modification could make system new to current users and break down their previous convention and understanding of reporting a medical incident. The relearning could cause frustration to expert users and be time consuming for both novice and expert users.

In task analysis, three factors were identified to largely affect users' performance of reporting. They are memory load, key stroke and mouse click. Comparing the two analysis results on existing and new incident reporting, the memory requirements of new one for manipulating interface and incident recalling were decreased largely. An impressive enhancement achieved is for answering event details. In the PSN system, it used many different widgets for such data collection including 2 single text fields, 2 multiple text fields, 4 pull-down lists, 10 radio/checkbox groups and 7 buttons. All of them laid out in a two screen high (screen resolution is 640x480 pixels) page. The users have to scroll the page back and forth and leap blindly among the confusing questions which are considered heavy burdens of memory load per cognitive theories. Furthermore, those two multiple text fields allowing up to 6,000 characters free text input can frustrate reporters and results in various levels of details of reporting. On the contrary, the counterpart of new design followed the Common Formats of AHRQ and set up less than 11 causal related questions in closed-ended format meeting the same goal. Such improvements not only lower the memory burden, but also can remarkably decrease the number of key strokes. On the other hand, though the number of mouse clicks is still as similar as it before, the actions of clicking became easier and less clicks could be achieved once reporter is a default user. For instance, a nurse reports an intraday incident. Obviously, the conciseness and easiness achieved by new interface is able to enhance reporting efficiency and users' satisfaction.

There is a trade-off we have to address. To avoid catastrophic errors may lead to design a less efficient user interface, such as adding extra questions to assure the user is certain about a particular answer or action. And adding auto-complete function to pull down list can save the time and lower the memory requirements but increase the number of key strokes. Therefore, it is not realistic for system design to achieve the best on all issues, such as three factors in this paper and unmentioned ones. What we should chase might be to make a balance for an acceptable compromise.

For heuristic evaluation results, each usability violation was categorized into 4 severity level according to its averaged rating score. They are catastrophic (rating > 3.5), major (2.5 <rating < 3.5), minor (1.5 < rating < 2.5), and cosmetic (rating < 1.5). Of 19 identified violations in total, there are 9 problems at the major level and 5 at the catastrophic level. These 14 problems consist of 4 Language ones, 3 Consistency violations, 2 Memory ones and each one in other five categories (Document, Error, Control, Flexibility and Minimalist), and 3 of 4 Language ones are usability catastrophes. All violations found in the first round of heuristic evaluation would be sequenced to steer enhancement of system usability.

To sum up, the task analysis and heuristic evaluation applied in this study can facilitate developers of volunteer medical incident reporting system at the initial stage of development cycle in fulfilling the users' needs and uncovering the flaws of usability concerns. Although it is not feasible to work out all the problems, these two steps will drive usability research into a system development cycle, especially for voluntary medical incident reporting system. As a result, usability problems could be iteratively identified and fixed, and users could be much easier and more satisfied of using voluntary medical incident reporting system over the time.

Future

The usability engineering is not a one-shot task but an iterative process with usability discovery and reinforcement. Furthermore, the development of a user-centered medical incident reporting system needs to establish a relation between different levels of users which is crucial to success of medical incident reporting applications. For instance, poorly unstructured incident datasets and lack system integration of the PSN have largely impeded system's usefulness. Much electronic medical

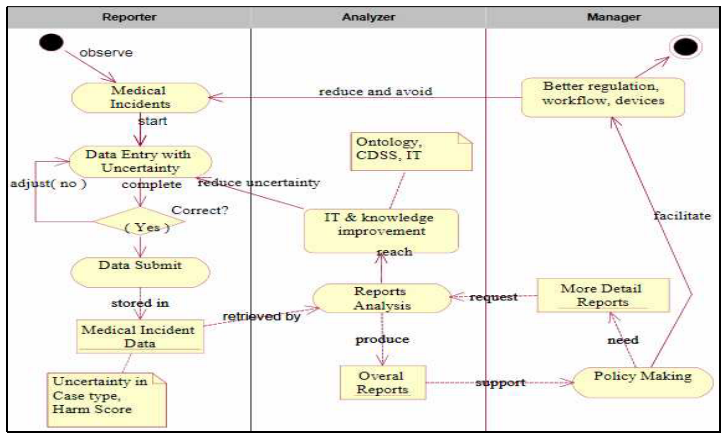

Figure 2-Iterative feedback cycle for voluntary medical incident repoting system

data have to be repeatedly entered into the PSN system and a big chunk of medical data in free text format shows inconsistency and impedes the application of data mining tools. Therefore, to advance our study we will emphasize collaborations between different systems and different types of users. The iterative development cycle shown in Figure 2 depicts collaborative feedback among three participating roles: reporters, analyzers and mangers. The reporters are in charge of data entry of observed medical incidents by reporting system. The quality of data stored in properly structured format is the key to validity of incident reports. The analysis reports will advance the applied technology and knowledge support for medical incident reporting for the purpose to diminish the uncertainty and other difficulties in reporting process. On the other hand, the analysis reports can be used to persuade managers of health unit to extend the usage of reporting system by administrative approaches, such as policy making. Ostensibly, the effective collaboration shown in Figure 2 could facilitate using and enhancement of voluntary medical incident reporting system. The more important is that the quality of care could be improved continuously with iterative enhancement of system performance and increasing use of reporting system.

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