Pertanika J. Soc. Sci. & Hum. 23 (S): 75 – 84 (2015)

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

A Review of Usability Challenges Identified in Health Information Technology

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ABSTRACT

User-centred design applies to processes in which end-users influence how a design takes shape. Usability engineering is now in the direction of the user-centred approach. This article addresses a review of its restrictions and challenges. Problems will be focused on healthcare as it is a critical system that may cause medical errors which can lead to the patient's injury or death. Through user interaction with healthcare devices/software, many usability problems have been identified including poor legibility, feature clutter, poorly distinguished alarms or alerts, lack of intelligent design, poor feedback on system behaviour, no provision for online help, poor support in local languages and right-handed design. Analysis of the usability evaluation technique was conducted to remedy the identified problems and meet the usability objective.

Keywords: Healthcare, Health Information Technology (HIT), infusion pump, usability challenges, Usability Evaluation Method (UEM)

INTRODUCTION

Health Information Technology (HIT) implies "the application of information processing involving both computer hardware and software that deals with the storage, retrieval, sharing, and use of health care information, data, and knowledge for communication and decision making" (Yen, 2010). HIT helps clinicians in offering effective and quality healthcare. On the other hand, just as HIT can provide potential benefits, without proper handling and poor requirement gathering prior to design, it can interrupt workflow, cause delays and introduce errors.

ARTICLE INFO

Article history:
Received: 30 March 2015
Accepted: 30 June 2015

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ISSN: 0128-7702

Healthcare systems are used by both clinicians and patients. In the course of usage, many usability problems can be identified including poor legibility, feature clutter, poorly distinguished alarms or alerts, lack of intelligent design, poor feedback on system behaviour, no provision for online help, poor support in local languages and right-handed design (Bhutkar *et al.*, 2013). A medical error report from the Institute of Medicine has greatly increased people's awareness of the frequency, magnitude, complexity and seriousness of medical errors (Jiajie, 2003). Thus, the need for evaluation of medical devices and healthcare application usability is essentially important.

Among the medical devices that require evaluation is the infusion pump. Infusion pumps are medical devices that deliver fluids, including nutrients and medications such as antibiotics, chemotherapy drugs and pain relievers into a patient's body in controlled amounts (FDA, 2014). The most common problems found with the infusion pump were with the "Change Mode" and the "Select New Patient" features. Use of the On/Off switch was identified as a common strategy to clear pump information and to escape incorrect navigation paths. The consequential contribution to patient safety of these problems ranged from non-hazardous to potentially very hazardous (Lamsdale *et al.*, 2005).

LITERATURE REVIEW

There are several healthcare usability evaluation methods (UEM) practised by usability professionals and system designers. UEM can be based on case studies or lessons learned that are collected from several experimental studies across many domains and organisations. Some well-known and widely used UEM include heuristic evaluation, cognitive walk-through, task analysis, video analysis, rapid prototyping, field study, goals, operators, methods, and selection rules (GOMS) analysis, usability testing, keystroke-level model (KLM), the think-aloud method, structured interview, cluster analysis and severity ratings (Ganesh, 2013).

In the hybrid model of usability, five essential usability characteristics were highlighted to be part of any product: learnability, allowing a user to easily start working with the system without training; efficiency, allowing a user of the system to accomplish a high level of productivity; memorability, enabling a user to use the system without relearning after a period of non-use; low error rate, enabling users to make fewer and easily rectifiable errors while using the system, and without disastrous errors; and satisfaction, allowing users to enjoy using the system.

To ensure a software project has these essential usability characteristics, usability researchers like Holzinger have special methods. Holzinger, for instance, used two methods: the inspection method (without end users) and the test method (with end users). The accompanying figure details these characteristics (Holzinger, 2005).

Inspection Methods

Usability inspection is the generic name for a set of methods that are based on having evaluators inspect the interface. Typically, usability inspection is aimed at finding usability problems in a design (Mark, 1994), although some methods also address issues like the severity of the usability problems and the overall usability of an entire design (Nielsen, 1993). Many inspection methods lend themselves to the inspection of user interface specifications (Nielsen, 1990) that have not necessarily been implemented yet, meaning that inspection can be performed early in the usability engineering life cycle (Nielsen, 1992).

TABLE 1
Comparison of Usability Evaluation Techniques (Holzinger, 2005)

	Inspection Methods			Test Methods		
	Heuristic Evaluation	Cognitive Walkthrough	Action Analysis	Thinking Aloud	Field Observation	Questionnaires
Applicably in Phase	all	all	design	design	final testing	all
Required Time	low	medium	high	high	medium	low
Needed Users	none	none	none	3+	20+	30+
Required Evaluators	3+	3+	1-2	1	1+	1
Required Equipment	low	low	low	high	medium	low
Required Expertise	medium	high	high	medium	high	low
Intrusive	no	no	no	yes	yes	no
Comparison of Usability Evaluation Techniques						

Heuristic evaluation. Heuristic evaluation is the most informal method and involves having a usability specialist judge whether each dialogue element follows established usability principles (Nielsen, 1990).

Cognitive walk-through. Cognitive walk-throughs use a more explicitly detailed procedure to simulate a user's problem-solving process at each step through the dialogue, checking if the simulated user's goals and memory content can be assumed to lead to the next correct action (Wharton, 1994).

Action analysis. The action analysis method is divided into formal and back-of-the-envelope action analysis; in both, the emphasis is on what the practitioners do rather than on what they say they do. The formal method requires close inspection of the action sequences a user performs to complete a task. This is also called keystroke level analysis (Holzinger, 2005). It involves breaking the task into individual actions such as move-mouse-to-menu or type-on-the-keyboard and calculating the times needed to perform the actions. Back-of-the-envelope analysis is less detailed and gives less precise results, but it can be performed much faster. This involves a similar walk-through of the actions a user will perform with regard to physical, cognitive and perceptual loading. To understand this thoroughly we must keep in mind that goals are external and that we achieve goals (Carroll, 2002).

Test Methods

Testing with end users is the most vital usability method and is very important. It offers direct data about how people utilise a system and their exact problems with a specific interface. There are several methods for testing usability; among the common are thinking aloud, field observation and questionnaires.

Thinking aloud. The think aloud method formally belongs to the verbal report method and stems from the field of cognitive psychology. It was specifically developed to gather information on the cognitive behaviour of humans when they were performing tasks. The think aloud method is viewed upon as particularly useful in understanding the processes of cognition because it assesses human cognition concurrently with its occurrence. It is, therefore, a unique source of information on these cognitive processes and a very direct method to gain insight into the way humans solve problems (Jaspers, 2009).

Field observation. Field observation is the simplest of all methods. It involves visiting one or more users in their workplace. Notes must be taken as unobtrusively as possible to avoid interfering with their work. Noise and disturbance can also lead to false results. Ideally, the observer should be virtually invisible to ensure normal working conditions. Sometimes video-recording is used to make the observation process less obtrusive, but it is rarely necessary. Observation focuses on major usability catastrophes that tend to be so glaring that they are obviously first-time occurrences and thus do not require repeated perusal of a recorded test session (Holzinger, 2005).

Questionnaire. The questionnaire was designed in a systematic way so as to capture both the passive and active experience of users. Careful consideration was given to ensure that the questions were arranged in a well synchronised manner so as to make correspondents have less difficulty as they answered the question; sufficient time was also given. In choosing the correspondents for the survey, it was also ensured that balance was struck in terms of users' exposure to the system. All of the above standards were adhered to so as to obtain a reliable data.

The analysis of the data obtained was done with the usage of standard data analysis tools and care was given to ensure that errors and false results were avoided. The final analysis was then subjected to proper checks in order to ensure that it was in consonance with other data from similar research.

METHODOLOGY

Fig.1 illustrates the approach used for this article. Journal articles regarding healthcare usability were searched using online journal databases and Google Scholar. Literature review and identification of problems were conducted simultaneously. Lastly, the analysis was based on finding ways to solve the identified problems without interfering or interrupting the whole system. This was done by studying other related systems and coming up with a more robust system that could eliminate the identified problems.

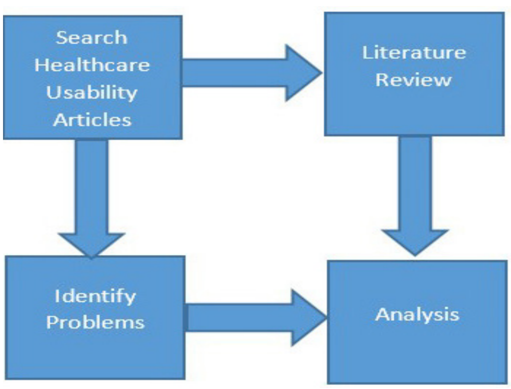

Fig.1: Methodology framework.

Test Case 1

A study was conducted in the Shock Trauma Air Rescue (STARS) Centre (Lamsdale *et al.*, 2005) using video and audio recording devices. The participants were 13 hospital nurses from different wards. The infusion pump used was Baxter (Fig.2) because it uses numerous advanced automated features.

Before the start of the study, two groups of participants each completed the 30-minute standard Baxter Colleague CX in-service performed by a Baxter Corporation clinical-training nurse. The in-service covered a general device overview (e.g. powering-on the device, display introduction, alarm and alert identification, tube loading and programming of primary and piggyback infusions) and an integrated protection system demonstration and also provided an opportunity for the participants to interact directly with the pump (Lamsdale *et al.*, 2005).

The next approach after in-service was think aloud; the participants were separately presented to the STARS simulation training centre and received instructions on the 'think-aloud protocol. This verbal protocol analysis captures the user's thought process descriptions as they complete the steps for each use case (Lamsdale *et al.*, 2005). A rehearsal was conducted to enable participants to become comfortable and used to the pump and with voicing the stages required for the think-aloud protocol.

Three use cases were presented to the nurses. Each case included background patient information, the supplies available, physicians' orders and additional instructions such as invoking the Guardian ™ integrated protection system when necessary (Lamsdale *et al.*, 2005). Demonstration of the use cases was equally balanced. Every participant was given 30 minutes to conduct the three use cases. The practice use case required the nurse to start a potassium chloride (KCl) infusion at 5mEq/hr and then to increase the amount of medication being infused to 10mEq/hr. The next use case dealt with a patient who was septic and hypotensive. The nurse had to infuse the antibiotic meropenem over a 15-minute period based on the concentration of the mini-bag. The nurse also had to administer a dopamine infusion at 5 mcg/kg/min, check the patient's vital signs and increase the amount to 10 mcg/kg/min. The final use case involved a patient who was having an acute myocardial infarction (MI) (Lamsdale *et al.*, 2005).

Fig.2: Baxter Infusion Pump (S. B. Dulak, 2005).

Test Case 2

This study was done using a one-channel volumetric infusion pump (Fig.3). Four individuals applied the defined heuristics to the user interfaces of two one-channel volumetric infusion pumps, identified usability problems in various areas/sections of the pumps and identified one or more heuristic violations for each usability problem. Two of the four evaluators were graduate students in the School of Health Information Sciences at UT Houston, and the other two were graduate students in the Department of Psychology at Rice University. They had taken at least one graduate level course on human factors or human-computer interaction. Before the evaluation, they were given a copy of the report of a heuristic evaluation conducted for a different product using a harmonised definition of heuristics (Jiajie, 2003).

They were then given instructions on how to conduct the evaluation by the first author of this paper, who is an expert in heuristic evaluation and has performed heuristic evaluations on several products. After the list of usability problems were discovered and heuristic violations were identified for each usability problem, the four evaluators independently assessed the severity of each usability problem. Their severity ratings were then averaged (Jiajie, 2003).

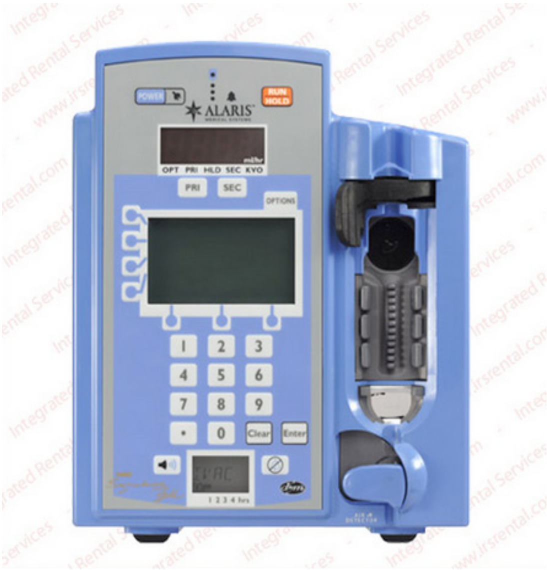

Fig.3: Alaris One Channel Volumetric Infusion Pump (www.dremed.com).

ANALYSIS

Data for the analysis were obtained based on the identified Useability Evaluation Methods defined in the literature review. The identified methods were the inspection method (heuristic evaluation, cognitive walkthrough and action analysis) and the test method (thinking aloud, field observation and questionnaire). Based on the analysis, the following deductions were made.

Test Case 1 Analysis

Recorded video and think-aloud scripts were scrutinised. During interaction with the infusion pump, the nurses made various mistakes, like thinking the infusion pump had only one channel instead of three; not reading feedback from the screen; and not conforming to the settings of the infusion pump. Nearly 80% of the nurses (78%) did not use the 'Change Mode' feature and incorrectly performed manual medication calculations instead of using the integrated protection system. The 'Select New Patient' feature was also problematic for 72% of the nurses when 'powering-on' the pump. Some nurses (25%) had difficulty loading the IV tubing into the pump's channel. Use of the On/Off switch was identified as a common strategy to clear pump information and to escape missed prompts or incorrect navigation paths (Lamsdale *et al.*, 2005).

Change mode. The Baxter 'change mode' attribute computes precise dose of drug in accordance with a regular set of concentration and time limits allocated by the nurse. In case two, the nurses were supposed to use the 'Change Mode' attribute to infuse meropenem, 1 gm IV q 8h over 15 minutes but they seemed to forget about the 'Change Mode' feature and did not engage the drug dosage protection system, which caused the administration of an improper amount of medication and concentration.

For this to be error free, there should be a barcode feature that recognises the drug name and concentration. If the system is nonproprietary, it could be feasible to contain a laser scanner on the interface. The nurses should just have to scan the barcode and the dosage and treatment schedule should be input into the infusion pump automatically. The feedback should be drug name and concentration to confirm to the nurses (users) that appropriate medication and action have been performed. Additionally, dosage procedure can be saved to reduce the rate of error. There is no need for patients on regular treatment to have their medication requirements entered every time.

Select new patient. The 'select new patient' function as provided by the devices comes up when the device is switched on and disappears after a few seconds if it is not selected as the device assumes it is still to be used on the last patient.

Users of the device found it hard to observe the 'select new patient' option when the device starts and also had difficulty resetting it for a new patient when the machine starts but displays the data of the previous patient. This can be solved by increasing the time during which the 'select new patient' option is shown when the device is switched on and also by making the option more clearly visible.

The design for the screen and buttons can also be enhanced so as to accommodate left-handed users as now the buttons are aligned for the right-handed, making it difficult for left-handed users to operate. To achieve this enhancement, the screen and the buttons should be centralised, modelled after the current Automated Teller Machine (ATM) as that can give ease of use to both left- and right-handed users of the system.

Test Case 2 Analysis

For Pump 1, heuristics were violated a total of 192 times. Consistency and visibility were the two most frequently violated heuristics (53 and 28, respectively). Feedback and match were the next most common violations (22 and 21). These four heuristics accounted for 64% of the violations. For Pump 2, heuristics were violated a total of 121 times. Visibility was the most frequently violated heuristic (29 violations). Memory and consistency were the next most common violations (19 and 17, respectively). These three heuristics comprised 54% of the violations (Jiajie, 2003).

A distinct case of visibility violation is when the 'enter' option is not pressed after the user enters the value for 'Rate' and 'VTBI' (volume to be infused). The user is shown a message 'complete entry' which sounds too ambiguous; a more appropriate response should be displayed to confirm values.

CONCLUSION

Healthcare is a very tricky environment with many dynamics that need to be taken into consideration and at times within a limited time frame that might be as little as a few seconds. As such, there is the need to equip the environment with not only the needed devices but to ensure that the devices are designed in such a way that the users will find no or very minimal difficulty in using the devices.

To guarantee the best utilisation of HIT, it is important to be focused on HIT usability, keeping in mind its envisioned users like physicians, nurses or pharmacists; intended tasks like medication management, free-text data entry or patient record search; and environment to be used like operation room, ward, or emergency room.

ACKNOWLEDGEMENTS

The authors wish to thank the Faculty of Creative Media and Innovative Technology, Infrastructure University Kuala Lumpur (IUKL) for their financial support to participate in IICON2014.

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