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Creation and Usability Testing of a Web-Based Pre-Scanning Radiology Patient Safety and History Questionnaire Set

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Recent advances in technology have significantly changed radiology workflow. The main focus of these changes has been the transition from hard copy film to digital imaging. The next transition will be a "paperless" transformation. Web-based versions of the current paper-based patient safety and history questionnaires were created using PHP and MySQL. Two rounds of usability testing using volunteers were completed using tablet PCs. Volunteers were comprised of ten individuals. Ages of volunteers ranged from 27 to 60 years, and there were eight males and two females. The majority of users had at least a Master's degree and was considered to have a computer experience level of a programmer. Eighty percent of the users agreed that the web-based questionnaires and tablet PCs were easy to use. Text input through the writing recognition window and scrolling proved to be the least usable sections of the questionnaires. The new web-based system was found to be a very usable system by our participants. The questionnaires were easy to use, easy to navigate, and easy to read. Individual elements such as radio buttons and checkboxes did not fair as well but were due to their small size. Difficulty with the writing recognition interface is an inherent issue with the Windows XP Tablet Edition operating system.

KEY WORDS: Usability, paperless, filmless, tablet PC, workflow

BACKGROUND

Recent advances in technology have significantly changed radiology workflow. The main focus of these changes has been the transition from hard copy film to digital imaging. This is advantageous in many ways; it increases workflow efficiency,[1,2] as the images are now acquired digitally and transmitted from the modality to the reading room for interpretation and stored digitally without printing film. The addition of the digital mammography unit has completed the process, allowing radiology to become "filmless."[3–5] There are exceptions to being filmless at many institutions, such as printing films for the operating rooms and films needed for outside referring physicians without the broadband access needed for Web browser-based image servers.

The conversion of the University of Utah Department of Radiology from hard-copy film to a filmless environment has had several beneficial effects. From October 2000 to October 2002, there was a decrease in the film printing costs from $3.45/exam to only $0.81/exam. During this same time period, there was a significant increase in technologist productivity, with an increase from 434 exams per FTE to 575 exams per FTE. There was also a decrease in the file room personnel from 16 FTE positions to nine positions. Radiology report turn around time decreased from over 41 h to less than 10 h. Inpatient throughput dropped from over 16 h to less than 8 h. There was also a

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significant increase in radiologist productivity, increasing from 1,493 relative value units (RVUs) per radiologist to 1,811 RVUs per radiologist. These are all examples of changes that have impacted patient care in a positive way at the university.[6]

The conversion of important patient information collected prior to a radiologic study would have a similar positive outcome on patient care. This information, including whether a patient has implant devices that are magnetic or contain sensitive electronics, is currently being stored separate from the patient's medical record on paper questionnaires. Approximately 6 weeks after image acquisition, the questionnaires are shredded to reduce the amount of space needed for storage. A system to digitally collect and archive patient safety and history pre-scan screening questionnaires could incorporate the information that is currently discarded in the patient's electronic medical record, notify technicians of potential issues, and inform radiologists at the time of interpretation. Information on the questionnaires could notify clinicians of the need to modify the protocol at the time of the study and draw attention to clinical information that may be overlooked or not readily available on the paper system currently in use. A system to digitize information gathered in patient forms is currently being used in the preoperative surgery waiting area in the new Eccles Critical Care Pavilion at the University of Utah and has received positive feedback.

This project addresses the next transition: making a filmless radiology department "paperless." The Philips Inturis Picture Archiving and Communications System (PACS) facilitates the transformation with the ability to scan in a page of paper, such as a patient questionnaire, and associate the scanned image with a DICOM data set. While this is a step toward being paperless, handwritten data is still collected on paper forms. Digitizing paper forms increases workload by adding steps for scanning the form and associating it with a study. While the form could then be viewed alongside the study, the handwritten information could not be used for decision support without being additionally analyzed by optical character recognition and natural language processing. Having patients answer preoperative assessments on a computer has been used as a method of data collection at the University of Utah. Digital assessments were first completed by patients on eChart, the prior EMR, and are currently used at the Critical Care Pavilion through a PowerChart (Cerner Corporation, Kansas City, MO, USA) interface. The purpose of this study was to create and test the usability of a similar system in the Department of Radiology. Utilizing the wireless network, patients will be able to input data via web-based questionnaire forms prior to the performance of radiologic studies. This system will be used for gathering both pre-procedure patient questionnaires and patient history screening sheets for magnetic resonance imaging (MRI) and computed tomography (CT).

METHODS

Hardware

A grant from the Department of Radiology was obtained early in the study process. The grant was used to acquire hardware in order to better facilitate the questionnaire project. A Universal 2U Dual Xeon Dual Core (Intel, Santa Clara, CA, USA) Storage Server was purchased, and two Toshiba Satellite R20 Convertible Tablet PCs (Toshiba America, New York, NY). The server was given the name Radquest and is used only for storing of the web files and database tables. The server was then loaded with the Apache server software (The Apache Software Foundation, 2007), PHP (PHP Group 2007), MySQL (MySQL AB, 2007), and the Java Run-Time Environment (Sun Microsystems, Inc., 2007). In order to be HIPAA compliant, security measures were put into place to limit access of this server by inappropriate parties. Security measures included IP tables and TCP wrappers, which were used to limit access to the machine to networked computers only. SELinux was installed, which is a policy manager that controls which protocols are able to run on the server and which resources may be accessed.

The Tablet PCs came with Windows XP Tablet Edition preloaded (Microsoft, Inc., 2007). We loaded all the needed software, including security certificates that were required for wireless fidelity (Wi-Fi) access. The XAMPP (Apache Friends 2007) server emulator was loaded on and used for testing to make sure the PHP pages would work on the Radquest server. The questionnaires

were individually loaded onto each tablet PC for the two stages of testing.

Questionnaire Creation

All questionnaires were created using the PHP server scripting language (The PHP Group 2007). Cascading style sheets (CSS) were used to give each questionnaire the same look and to be able to switch font and element sizes on the fly. An example of the questionnaires can be seen in Figure 1. Additional script programming using the JSP and JavaScript languages (Sun Microsystems, Inc., 2007) was also used. A database was created using

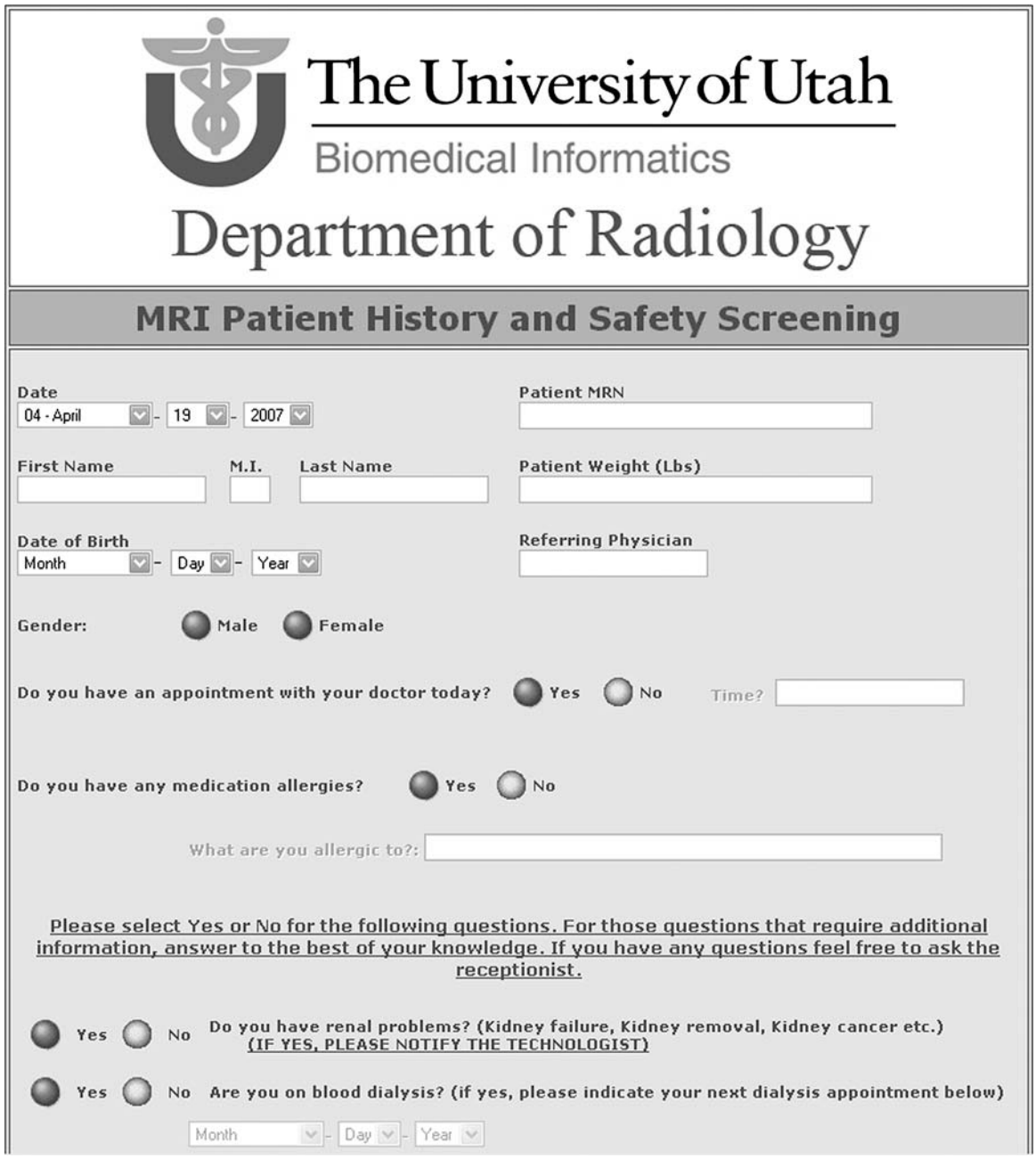

Fig 1. Questionnaire example.

the MySQL database management system (MySQL AB, 2007) with multiple tables being populated with SNOMED CT codes (SNOMED International, 2007)[7] pertinent to all the questionnaires. Two additional tables with patient-centered information were created, one for patient demographics and one for patient questionnaire answers.

Usability

Two rounds of usability testing were performed throughout the study period. The MRI Patient History and Safety Questionnaire and the Chest, Abdomen, and Pelvis MRI Patient History Questionnaire were used as representatives of the entire questionnaire set. Subjects from the first two testing stages did not complete all of the demographic information for privacy and confidentiality concerns. Age and gender for the initial two stages were the only collected demographic information. After completion of both questionnaires, subjects were directed to an online survey created using Opinio software (ObjectPlanet, Inc., 2007) to assess the usability of the questionnaires. The set of questions asked were scored using the Likert[8,9] five-point system and a few open-ended questions for subjects to describe improvements that were needed.

Stage I

Students from the Biomedical Informatics department were recruited via email. Test subjects met in a selected room in the Health Science Education Building (HSEB) for testing. A Toshiba convertible tablet PC was used for the testing phase with participants using the tablet stylus to complete the questionnaire and survey. Each participant was instructed to use all aspects of the two questionnaires multiple times in order to fully understand each. The number of participants was limited to five for this initial stage. As stated above, only minimal demographic data was acquired during this testing period.

Stage II

Residents, faculty, and staff from the Department of Radiology in the School of Medicine were recruited via email to help assess the questionnaires. Methods used in stage I were repeated in this stage. The number of participants for this portion of the study was limited to 5.

Statistical Methods, Data Analysis, and Interpretation

The study used both qualitative and quantitative data collection. The Likert questions were composed on a five-point scale between "strongly agree" and "strongly disagree." Questions were formulated to determine usability of the questionnaires as a whole, the tablet and stylus interface, and the individual elements of the questionnaires. Open-ended questions to determine the best aspects, worst aspects, and suggestions for improvements were included for qualitative data. Means of each question and percentages of each answer given to the questions were determined to gauge overall usability of the system determined by the participants. Qualitative answers were interpreted by the study team for possible improvements in the web-based system.

RESULTS

Usability

Results from the usability testing were combined for the two groups. The groups consisted of ten individuals, eight men and two women. The ages ranged from 27 to 60 years. The majority of individuals had at least a master's degree (60%). Reported computer experience was high as well with the majority (60%) having the experience of a programmer. The majority of users agreed the questionnaires were easy to use (median, 4.0; SD= 0.47), easy to navigate (median, 4.0; SD=0.82), and the forms were easy to look at (median, 4.0; SD=0.67.) Bar graphs for this data can be found in Figure 2.

The majority of users found the tablets easy to use (median, 4.0; SD=0.88) and the stylus easy to use with the tablet (median, 4.0; SD=1.34; Fig. 2). One question was asked to compare the ease of use of the stylus with that of the keyboard, but the PC was only used in tablet mode so the keyboard was not accessible during testing. This question was eliminated from statistical calculation for this reason.

Responses for the individual elements varied. Only 50% of users agreed or strongly agreed that

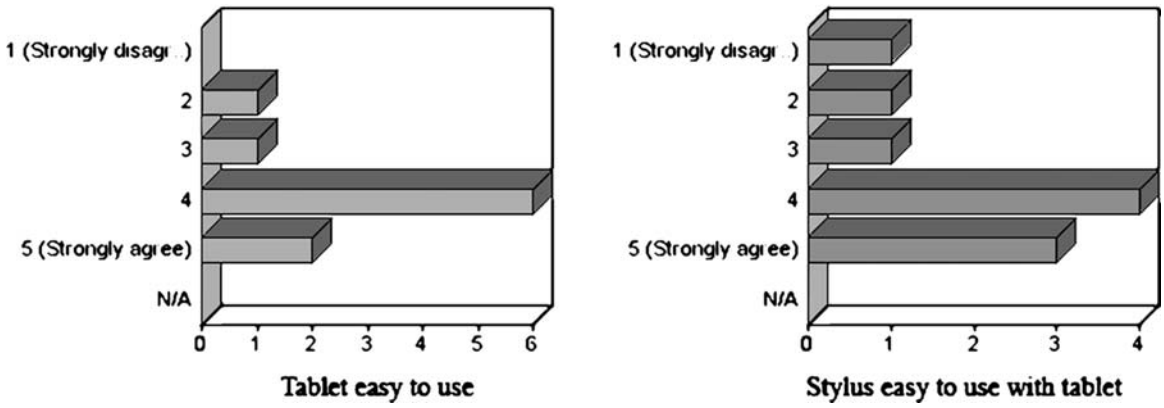

Fig 2. Tablet usability.

radio buttons were easy to use (median, 4.0; SD= 1.0). Seventy percent of users agreed or strongly agreed that checkboxes were easy to use (median, 4.0; SD=1.06). Users agreed or strongly agreed that drop-down boxes were easy to navigate 80% of the time (median, 4.0; SD=0.5). Seventy percent of users agreed or strongly agreed that both font size and type were easy to read (median, 4.0/4.0; SD=0.92/0.67). Bar graphs can be seen in Figure 3.

The open-ended questions had a variety of comments related to the questionnaires. The radio buttons are mentioned five times as elements that work well. Writing recognition, check boxes, and the drop-down menus were mentioned once apiece as elements that work well. The element that users thought worked the least was the text entry method with the writing recognition window. Four users mentioned this element. The only other element mentioned was the radio buttons.

Improvements that users thought would improve the questionnaires were comments related to difficulty with scrolling. Comments like "...use tabs instead of one long scrolling form..." and "Use the maximum screen height, not the scroll bars. Have the patient push 'next' a few more

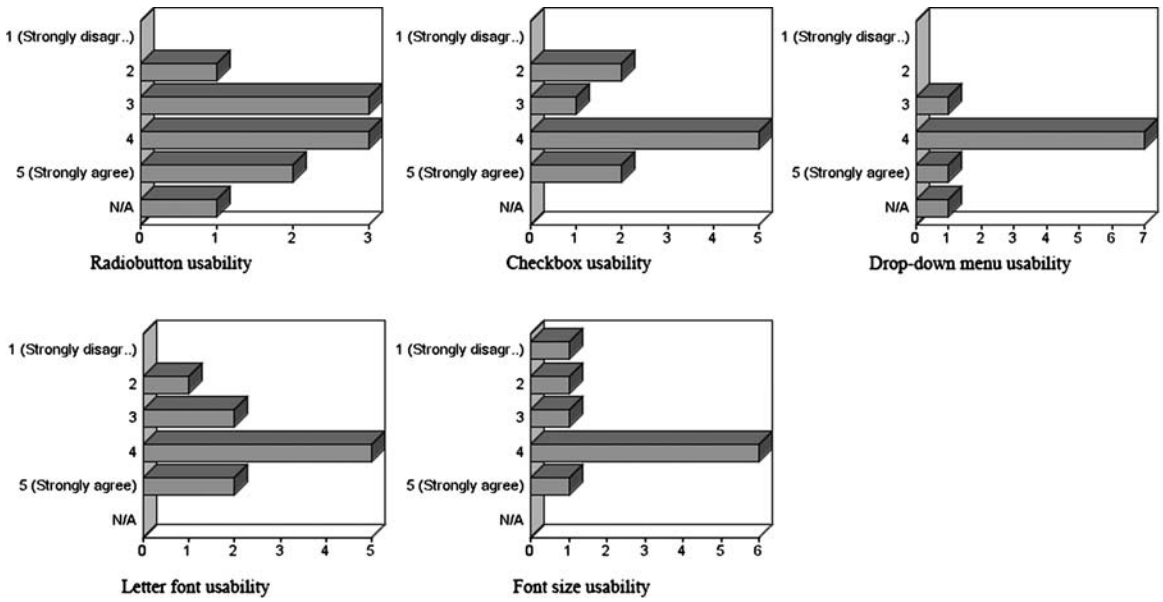

Fig 3. Individual element usability.

times instead of scrolling." Enlarging the font size and increasing the size of the radio buttons were mentioned as improvements once each.

DISCUSSION

A Usable System

The results of the usability testing showed the system to be very usable that was able to span both age and computer experience. Research suggests that only four to five individuals are needed in order to expose 80% of the usability issues with a given system.[11] The use of ten individuals for this study was to ensure that the majority of deficiencies were accounted for and corrected.

Questionnaire Changes

Changes were made to the questionnaires prior to the second stage of the usability testing. This was done to correct for problems commented on in the first stage and then to test the new changes to make sure new problems did not arise. An introductory page instructing users how to use the tablet and questionnaire features was created and was the initial starting page for the second stage of testing. Hidden sub-questions from the initial questionnaires were changed to a "grayed out" version so the length of each questionnaire was static.

Problems with scrolling has been found in other studies to be an issue with tablet PCs.[11] It also has been found as an issue in all web-based pages and has been suggested as a thing to be avoided.[11] The issue was corrected in this instance using anchors throughout the questionnaires with "top," "next," and "previous" links, and splitting each questionnaire into page lengths, a process referred to as 'paging.'[12]

The problem with radio buttons was one of the more difficult elements to correct and, because of this, were not altered until after both usability testing stages. Other studies have shown that these elements do not work well, particularly in the elderly.[12] FormStyle is an open source method for changing both radio button and check box elements using a combination of JavaScript and CSS.[13] FormStyle works by surrounding HTML form elements in a "span" tag. Images within the CSS are used to replace form elements by using the "class" attribute of the "span" tag. In Figure 4, there is a comparison of the default HTML elements and the changes made when using FormStyle.

Tablet Usability

Overall, the tablet PCs worked well in this study. The ease of use was good for both the tablet

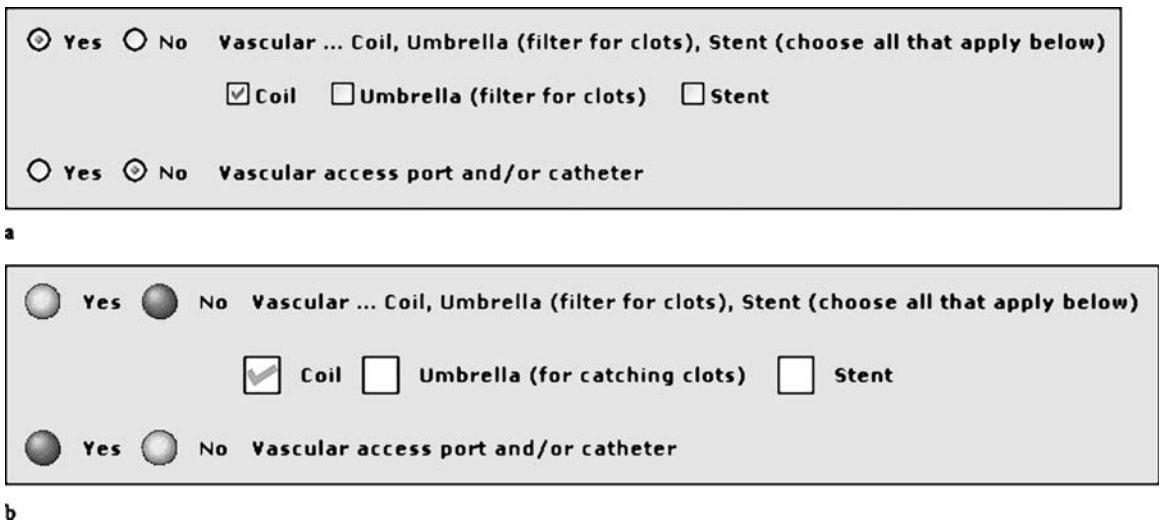

Fig 4. Radio buttons before and after Formstyle.

themselves and the stylus. Text entry via the writing recognition window did not work well and was one of the most commented on elements. This phenomenon could have been a result of the newer technology as even those with a high level of computer experience had difficulty using it. The writing recognition window does learn as it goes, that is as more samples are given and corrected, the system gets better at recognizing the user's handwriting. In our workflow, users would not be using the system long enough for the computer to become more efficient. Unfortunately, this was one element we had no control over as it was a product of the tablet operating system. As this questionnaire set is designed for patient's to fill-out a few forms only, this will continue to be a challenge in the system. If this continues to be a problem, it is likely that we will switch to using a combination of the stylus and keyboard.

Study Limitations

The results from this study do have some limitations as the participants do not necessarily represent the average patient population. Education and computer experience were elevated in the test group. Repeat testing using the actual patient population will serve to address usability issues that the standard patient may have while using this system.

The web-based questionnaire set is a usable means of collecting information from patients prior to undergoing a CT or MRI study. Further testing with actual patients and implementation into the health science system will allow for further testing and determination of its usefulness and patient satisfaction.

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