Context Sensitive Health Informatics: Many Places, Many Users, Many Contexts, Many Uses
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Usability Evaluation of a Medication Reconciliation and Allergy Review (MRAR) Kiosk: A Methodological Approach for Analyzing User Interactions

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Abstract. Internationally, major efforts are underway to improve medication safety and reduce medication errors during transitions of care. One strategy that has emerged to improve data accuracy and close information gaps is the introduction of software applications and workflow models that allow patients to review, enter, and modify their own patient data (e.g. information about medications they are taking). Evaluating the quality and effectiveness of such patient-facing healthcare applications is critical, especially when this approach is applied to high-stakes clinical tasks such as medication reconciliation. In this paper we describe an approach that has been used to assess the usability of a patient-facing medication reconciliation and allergy review (MRAR) kiosk. The phases involved are described along with implications and challenges of carrying out this work.

Keywords. Medication reconciliation, allergy review, usability engineering, usability testing, usability inspection, patient kiosk

Introduction

There have been major efforts nationally and internationally to reduce medication errors at transitions of care. Medication reconciliation (MR) – a standardized method for comparing patient medication adherence to organizational documentation – has been heralded as an effective way to close information gaps and improve patient communication [1-3]. Along these lines, Lesselroth and colleagues at the NorthWest Innovation Center, based at the United States Veterans Affairs Portland Health Care System (VAPORHCS), pioneered the use of patient self-service kiosks to collect data about medication adherence. The Automated Patient History Intake Device (APHID) is a novel software application accessed using a kiosk located in the clinic lobby. It allows patients to review the names, dosage and frequency of their medications prior to their appointments [4]. The system automatically generates a report in the health record for a provider to review with the patient during the interview. Time-motion analysis and discrete event simulation indicated the approach could integrate into

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workflow [5]. Also, a provider survey of tool adoption indicated that most respondents thought the device improved patient safety [6].

Within the last year, the VAPORHCS team conducted a usability evaluation on the patient interface of medication review and allergy review (MRAR) software to determine its effectiveness in gathering structured data for business analytics. A variety of health systems assessment methods have been employed in the literature [7]. One method is heuristic evaluation, whereby one or more analysts step through the user interface, noting violations of standard heuristics [8]. Another method is known as usability testing, whereby participants are observed using the system to complete tasks or scenarios. Previous research has shown that expert inspection and test scenarios can be complementary. Findings can be integrated to improve validity and provide a more robust picture of usability issues besetting health information systems [9]. Furthermore, there are now a number of rapid usability testing methods such as the rapid low-cost usability engineering method [10] and the Rapid Usability Evaluation [11] that combine methods to improve the speed of knowledge creation and compress the development lifecycle. In addition, the term "clinical simulation" has begun to be applied to highlight the simulation aspects of testing involving realistic use cases, settings and contexts [12].

In this paper, we describe an integrated methodological approach to evaluating the usability of MRAR patient interfaces. The rationale behind the approach and some key usability findings from this type of integrated evaluation will be discussed.

1. Methodologic Approach

Our Innovation Team applied a multi-phase approach that integrated a heuristic evaluation with usability testing (as shown in Figure 1 and described below). The goals of testing were to: 1) estimate the learnability and ease of use of the interface; 2) identify and prioritize design concerns that might limit adoption or effectiveness; 3) identify data validity risks that might affect device safety. To describe each phase, we offer herein a case study describing the evaluation of the MRAR at the VAPORHCS.

Phase 1 – Generation of Evaluation Questions:
The team generated questions to determine whether the user interface and workflow would permit patients to complete designated tasks effectively, efficiently and safely. Questions included: Can patients understand the information displayed? Can they identify discrepancies in their medications? Can they learn how to enter new medication information?

Phase 2 – Scenario (Use Case) Development:
The team next created a set of use cases to apply to both heuristic evaluation and usability testing. The software's functional requirements drove use case content. To determine the minimum number of use cases required, a table was created that listed each functional component and the allowable inputs (e.g., user responses, software states, environmental conditions) for that component [13]. We then designed use cases that enabled us to evaluate the behavior of each function in response to a given input (see Figure 2). In our example, 15 use cases were developed to test the following tasks: review medication information, identify medication discrepancies, identify out-of-date medications, and enter new medications. For each use case, a single corresponding

simulation (including an exit interview) was written for heuristic evaluation and usability testing.

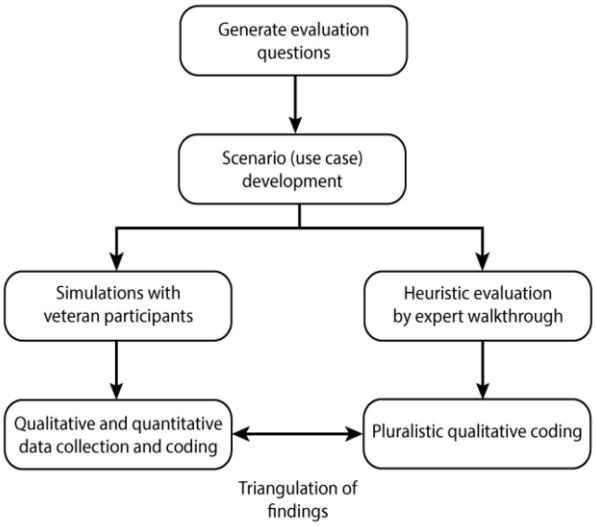

Figure 1. Multi-phase approach to analysis of kiosk use by patients.

Use case: Enter medication discrepancies

Description: A patient has medications on file in the local electronic health record. The patient completes a medication review session and must indicate information changes. The patient adjudicates perceived errors in the prescription list using the touch-screen controls and the comments input capability.

System state:
- active local prescription for lisinopril
- active over-the-counter record for vitamin D
- expired prescription for albuterol

Goals:
- Determine to what extent participant understands on-screen information.
- Verify the participant can designate a descrepancy in the prescription.
- Assess how easy a participant can add information about a new medication.

Conditions and inputs:
- Patient is on time for appointment.
- Patient is taking lisinopril and requests a refill.
- Patient is taking vitamin D according to a different schedule.
- Patient is not taking albuterol and indicates it causes tremors.

Figure 2. Example use-case.

Phase 3 – Heuristic Evaluation by Expert Walkthrough:
For each task, subject matter experts on the team completed a heuristic evaluation using a published rating instrument that measured Nielsen's ten heuristics [9]: Aesthetics, Control, Documentation, Error Prevention, Flexibility, Help, Match, Recognition, Standards, and Visibility. Each finding was documented and assigned one or more usability violation codes on a collection form with screenshots. Several evaluators independently completed the evaluation; discrepancies were resolved through discussion.

Phase 4 – Usability Testing with Participants:
Usability testing was broken into sub-tasks: 1) recruit a user sample, 2) observe subjects completing use-cases, and 3) perform a short exit interview. We used a screening instrument to select subjects (US veteran patients actively enrolled and receiving care at our medical center) based upon age, level of health, and eHealth literacy. To be included in the study, participants had to have at least 3 active prescriptions and must have previously used an automated teller machine (ATM). Participants were furnished with a set of simulated tasks to complete (identified in Phase 2) and encouraged to use the Think-Aloud technique while one or more researchers collected observational data [11]. In our example, this involved recruiting a convenience sample of 17 veterans (average age 68 years) with scheduled clinic appointments. We escorted subjects to a simulation laboratory equipped with a kiosk linked to a test database. The study team recorded interface performance on an instrument that included task goals, anticipated workflow, and sample interface screens. The team recorded task completion rates, qualitative descriptions of participant behaviors (including sample quotes), and design issues marked on the printed screenshots. In addition, a set of open-ended questions drove a semi-structured post-task interview about whether participants found the information easy to understand, and if they found the tasks easy to complete or not. After each participant session, the study team reviewed all findings together, assigned a usability violation code using Nielsen's categories in a top-down manner, and organized interface specific problems into bottom-up categories based upon screen design, function, or workflow point.

Phase 5 – Data Coding, Analysis, and Triangulation of Findings:
For each task, function, or screen (identified in Phase 2), the team noted in a findings table: 1) root-cause heuristic violations, 2) interface design problems, and 3) a consolidated list of user problems prioritized by frequency (see Table 1 for a representative sample). Findings were recorded independently for each method and then combined. There was a modest degree of overlap between methods; many findings were only identified using one method. For findings that appeared in both methods, root-cause heuristic codes were compared and either combined or adjudicated based upon team review and consensus. By applying the same top-down heuristic codes to both methods and then comparing findings, the team was able to 1) assess the degree of correspondence identified through either method (an estimate of criterion validity), 2) speculate upon the root-causes of user error (an estimate of construct validity), and 3) furnish a more complete evaluation to developers.

Phase 6 – Summarization and Reporting:
All results and issues identified in phases 3, 4 and 5 were summarized using several methods. We aggregated major or recurrent heuristic and design themes into a table for developers. The team also collected granular observations and errors in a requirements traceability matrix to help map design specifications to actual performance. Finally, a major findings "map" – a graphic display of the software workflow – was drawn out with the key failure points highlighted. This format was intended to help the architects and software engineers visualize the "stress-points" in the workflow.

2. Results

The multiphase approach outlined above proved to be an efficient method for identifying usability concerns (summarized in Table 1). First, simulation testing helped recognize interface design and visibility problems (e.g., participants frequently failed to see or use the "Add comments" button). Second, by observing users entering comments with the interface, the team identified a number of workflow and navigation missteps. Third, using two techniques in combination surfaced more usability findings than either would have alone. In circumstances where findings overlapped, usability testing tended to validate concerns identified during heuristic evaluation while heuristic evaluation helped focus the observation sessions and attach root causes to error. Overall, both evaluation methods revealed that free text entry tasks were challenging for veteran patient participants to complete or track for consistency and recording. The feedback from the evaluation is currently being used to revise and optimize the patient-facing user interface for a further round of evaluation and testing.

Table 1. Major findings map to the key software functions and workflow paths. In many instances, findings were identified using both usability methods.

Method	Requirement	Screen	Finding/Heuristic Violation
Simulation	Patient should be able to enter a comment about each prescription	"Current medication review"	Participants did not notice or identify the "Add comment" button
Simulation/ heuristic inspection	Patients can select a comment using pre-filled response buttons	"Add comment"	Participants did not know if selections were confirmed or saved; consistency of design violation
Heuristic inspection	Saved input should match pre-filled response buttons	"Add comment"	Pre-filled response buttons inserted string fragments; mental model violation
Simulation	Patients should be able to enter a free text comment	"Add other comment"	Participants did not notice or identify "Other" option
Heuristic inspection	Patients should be able see and verify their input	"Add other comment"	Cannot determine what content is saved with multiple entries; visibility of status violation
Simulation/ heuristic inspection	Patients should be able to enter a free text comment	"Keyboard and entry dialog"	Participants did not understand instructions; participants struggled with format and entry; consistency of design violation
Heuristic inspection	Patients should be able to see when entries are large	"Keyboard and entry dialog	Limited ability to view and scroll through large text blocks; mental model violation
Simulation/ heuristic inspection	Patients should be prompted to report any over-the-counter agents	"Additional products prompt"	Participants thought the instructions were difficult to understand; help documentation violation

Method	Requirement	Screen	Finding/Heuristic Violation
Simulation/ heuristic inspection	Patients should enter and save each product name one at a time	"Additional products entry"	Participants typed multiple responses in one entry; participants could not recall prior entries; mental model violation
Heuristic inspection	Patients should be able to see that new items have been saved	"Additional products entry"	Information did not clearly indicate information was saved; visibility of status violation
Simulation/ heuristic inspection	Patients should be able to modify entries with frequency and instructions	"Frequency and direction"	Participants did not understand how to complete task; error prevention and recovery violation
Simulation/ heuristic violation	Patients should be able to confirm or correct entries	"Summary and confirmation screen"	Participants did not recognize the entries could be edited individually; mental model violation
Heuristic inspection	Contents should be consistently rendered on screen	"Summary and confirmation screen"	Order of items shifted unpredictably when editing contents
Simulation	Patients should be furnished with controls to correct entries	"Additional products edit"	Participants did understand goals of interface or how to update frequency/instructions
Simulation	Patients should be able to close a session at any point and receive confirmation	"Exit program feature"	Participants did not always notice or identify the "Exit" button and feared losing data

3. Methodologic Issues

We encountered a number of methodologic issues during usability testing with participants. For example, in the simulations it was difficult for participants to relate to cases that did not match their own personal medical conditions (i.e., many struggled with the abstract thinking required to assume a hypothetical role in the scenarios). In addition, local Institutional Review Board policies governing quality improvement efforts with enrolled veteran patients prohibited collection of audio or video data.

4. Discussion and Future Work

This paper has presented the framework for a mixed-method assessment combining heuristic evaluation with 'typical' usability testing (i.e. representative end-users completing use cases). We are using the approach that we have piloted and described in this paper for a full scale evaluation including usability tests of a complementary provider-facing interface. Another area of study is the refinement of use case and task generation that subjects find "natural". A further planned extension of the approach described in this paper is to conduct naturalistic recording of use of MRAR for real patient interactions. In addition, because health literacy appears to be a major factor in the adoption of such technology, the relation of eHealth literacy and patients' ability to effectively use the MRAR is another area that is currently being targeted by the authors for future research work.

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