Journal of Biomedical Informatics 66 (2017) 11–18

Contents lists available at ScienceDirect

Journal of Biomedical Informatics

journal homepage: www.elsevier.com/locate/yjbin

Pilot evaluation of a method to assess prescribers' information processing of medication alerts

Alissa L. Russ [a,b,c,*], Brittany L. Melton [d], Joanne K. Daggy [e], Jason J. Saleem [f]

[a] Center for Health Information and Communication, Department of Veterans Affairs (VA), Veterans Health Administration, Health Services Research and Development Service, Richard L. Roudebush VA Medical Center, Indianapolis, IN, United States
[b] Regenstrief Institute, Inc., Indianapolis, IN, United States
[c] College of Pharmacy, Purdue University, West Lafayette, IN, United States
[d] School of Pharmacy, University of Kansas, Lawrence, KS, United States
[e] Department of Biostatistics, Indiana University School of Medicine, Indianapolis, IN, United States
[f] Department of Industrial Engineering, University of Louisville, Louisville, KY, United States

ARTICLE INFO

Article history:
Received 25 February 2016
Revised 12 October 2016
Accepted 27 November 2016
Available online 28 November 2016

Keywords:
Human factors and ergonomics
Cognition
Alert systems, medication
Patient safety
User-computer interface
Decision support systems, clinical

ABSTRACT

Background: Prescribers commonly receive alerts during medication ordering. Prescribers work in a complex, time-pressured environment; to enhance the effectiveness of safety alerts, the effort needed to cognitively process these alerts should be minimized. Methods to evaluate the extent to which computerized alerts support prescribers' information processing are lacking.
Objective: To develop a methodological protocol to assess the extent to which alerts support prescribers' information processing at-a-glance; specifically, the incorporation of information into their working memory. We hypothesized that the method would be feasible and that we would be able to detect a significant difference in prescribers' information processing with a revised alert display that incorporates warning design guidelines compared to the original alert display.
Methods: A counterbalanced, within-subject study was conducted with 20 prescribers in a human-computer interaction laboratory. We tested a single alert that was displayed in two different ways. Prescribers were informed that an alert would appear for 10 s. After the alert was shown, a white screen was displayed, and prescribers were asked to verbally describe what they saw; indicate how many total warnings; and describe anything else they remembered about the alert. We measured information processing via the accuracy of prescribers' free recall and their ability to identify that three warning messages were present. Two analysts independently evaluated participants' responses against a comprehensive catalog of alert elements and then discussed discrepancies until reaching consensus.
Results: This feasibility study demonstrated that the method seemed to be effective for evaluating prescribers' information processing of medication alert displays. With this method, we were able to detect significant differences in prescribers' recall of alert information. The proportion of total data elements that prescribers were able to accurately recall was significantly greater for the revised versus original alert display ($p = 0.006$). With the revised display, more prescribers accurately reported that three warnings were shown ($p = 0.002$).
Conclusions: The methodological protocol was feasible for evaluating the alert display and yielded important findings on prescribers' information processing. Study methods supplement traditional usability evaluation methods and may be useful for evaluating information processing of other healthcare technologies.

Published by Elsevier Inc.

1. Introduction

Over 1.2 million medication errors are estimated to occur annually in the United States [1]. Computerized medication alerts can warn prescribers about medication allergies, drug-drug interactions, and other safety issues to influence prescribing decisions and enhance patient safety. As part of the Meaningful Use criteria

* Corresponding author. Roudebush VA Medical Center, VA HSR&D Center for Health Information and Communication, CHIC, 1481 W. 10th St., 11-H, Indianapolis, IN 46202, United States.
E-mail address: alissa.russ@va.gov (A.L. Russ).

http://dx.doi.org/10.1016/j.jbi.2016.11.011
1532-0464/Published by Elsevier Inc.

[2], electronic health record systems are required to include medication alerts to warn prescribers about medication allergies and drug-drug interactions before medications are dispensed to patients. Medication alerts serve a range of functions and types of end-users, including warning novice prescribers (e.g., residents) about potentially unsafe orders and notifying prescribers about drug-drug interactions that are newly identified by the literature. Alerts are also intended to provide clinical decision support to "expert" prescribers and pharmacists, by notifying them of safety concerns they are familiar with, but overlooked; in this case, alerts provide cues that may help them retrieve information from their existing knowledge [3] to inform medication decision-making. Alerts occur frequently during medication ordering. For example, an audit of physician entered medication orders found that approximately 13% of orders resulted in at least one allergy or drug-drug interaction alert [4]; the frequency of alerts overall is presumed to be higher than this, since this estimate does not account for the many other types of medication alerts, such as duplicate drug alerts or drug-disease alerts. Studies report that alert override rates range from 25% to 96% of alerts, with the rate of inappropriate overrides varying from 8% to 82% of alerts [5]. Given the number of alerts and associated safety implications, alert displays should support rapid information processing. Recently, the scientific community has focused attention on developing alert displays that reduce cognitive burden [6–8], with the goal that prescribers can process alerts at-a-glance [9].

Information on the alert interface must be cognitively processed by the recipient in order for the warning to be effective [10]. Lehto [11] outlines five basic stages of human information processing for warnings. Applied to prescribers and alerts, these stages include: (1) exposure to an alert; (2) perceiving the alert message; (3) incorporating alert information into working memory and retrieving related knowledge; (4) decision-making; and (5) response. Cognitive processing is one of the steps that is needed for warning effectiveness. In stages 2–3 especially, it is important to minimize the effort needed to acquire the information from the warning [10]. Rogers et al. [12] state that "external information on the warning [that] must be translated into some internal representation via reading verbal information, recognizing pictorial information, or decoding pictorials and symbols". Given the number of medication alerts and time pressured clinical environment, it is important that alerts support accurate information processing over short exposure durations. In addition, one alert often presents multiple warning messages, and it is especially important that high risk warnings, such as adverse drug reactions and high severity drug-drug interactions, facilitate accurate information processing.

A few studies assessed the usability of medication alert interfaces via traditional techniques such as think aloud, time on task, and usability surveys [13,14]. These studies are essential, but provide limited information on prescribers' information processing of alerts. There have been many studies of information processing across several domains and applications. One review summarized literature on other types of visual warnings, including studies of information processing [12]. Several factors influence information processing of visual warnings including, but not limited to: color, font size, layout, terminology, familiarity, and hazard perception [12]. Several studies assess information processing by measuring individual's recall of warning information [12,15]. In healthcare, studies have primarily focused on individuals' information processing of medication labels [16,17]. We did not identify any studies that examined prescribers' information processing of medication alerts. To our knowledge, researchers have not evaluated the extent to which medication alerts displays support prescribers' information processing at-a-glance, and methods for accomplishing this goal are not well defined.

Our objective was to develop and pilot a methodologic protocol to assess the extent to which alerts support prescribers' information processing – specifically, the incorporation of information into working memory – over a short viewing duration and evaluate whether this method is feasible. Our primary hypothesis was that, with this method, we would be able to detect a significant difference in prescribers' information processing with a revised display that incorporates warning design guidelines, compared to the original alert display, measured by the proportion of display elements that prescribers accurately recall. Secondary hypotheses were that, for the revised versus original display, we would detect a significant difference for each of the following: (a) proportion of elements common to both displays that prescribers are able to accurately recall; (b) proportion of unique display elements that are accurately recalled; and (c) proportion of prescribers who accurately recall the total number of warnings present. We piloted this protocol by evaluating one alert that contained three warning messages. This research is part of a larger investigation where we applied human factors principles to generate a novel display for medication alerts. Previously, we reported results for alert usability and prescribing errors [6]. In this article, we describe a separate aspect of the study, where we developed a methodologic protocol to assess prescribers' information processing of alerts.

2. Theoretical background

The working memory model by Baddeley and Hitch [18] has implications for software design, including the design of medication alerts. They describe a three-part model of working memory. In a simplified description, this model consists of the central executive, which coordinates information from two temporary storage systems: the phonological loop and visuospatial sketch pad, for storing speech-based information and visuospatial imagery, respectively [19]. The storage capacities of these systems are limited [20], although the skilled memory theory of Ericsson and Kintsch [3] proposes that experts are able to leverage long-term memory to expand their working memory capacity to some extent – for particular domains and activities – after sufficient training and practice. Regardless, a basic tenet of design is to minimize information burden on end-users' working memory stores [20]. According to Wickens and Carswell, a large body of working memory research has evaluated tasks where information is provided to subjects in "discrete batches", with the research goal that subjects are able to remember as much of the information as possible [20]. Oftentimes, this involves developing designs that encourage "chunking" or grouping of information, which can increase subjects' ability to recall information [20]. Therefore, consistent with these previous research methods, we sought a method that would allow us to evaluate the extent to which alert designs support prescribers' ability to incorporate information into working memory.

There are a variety of cognitive analysis methods that have been used to inform the design of health information technologies [21–24]. One of the most widely used methods is the think aloud technique [25,26], which originates from the field of cognitive psychology [27,28] For this technique, participants are asked to concurrently verbalize their thoughts as they complete tasks [21]. Think aloud inherently elicits a wide variety of verbalizations across tasks and participants, depending upon the characteristics of the end-users and the types of usability problems that each individual encounters. This technique provides insight into how humans problem-solve and helps evaluators identify usability errors, which can then inform more advanced software designs [23]. In this particular research, our goal was *not* focused on identifying usability errors, however, but to systematically assess the