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Usability evaluation of an emergency department information system prototype designed using cognitive systems engineering techniques

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ABSTRACT

This article presents an evaluation of novel display concepts for an emergency department information system (EDIS) designed using cognitive systems engineering methods. EDISs assist emergency medicine staff with tracking patient care and ED resource allocation. Participants performed patient planning and orientation tasks using the EDIS displays and rated the display's ability to support various cognitive performance objectives along with the usability, usefulness, and predicted frequency of use for 18 system components. Mean ratings were positive for cognitive performance support objectives, usability, usefulness, and frequency of use, demonstrating the successful application of design methods to create useful and usable EDIS concepts that provide cognitive support for emergency medicine staff. Nurse and provider roles had significantly different perceptions of the usability and usefulness of certain EDIS components, suggesting that they have different information needs while working.

1. Introduction

Emergency department (ED) patient status boards display patient information and support the activities of ED staff including physicians, nurses, other care providers (e.g., physician assistants) and technicians. Patient status boards are used to track the status of patients and resources, providing support for task completion as well as shared awareness among clinical team members (Wears et al., 2007). Because the emergency department environment is characterized by high acuity patients, intense time pressures, and inconsistent patient arrivals, patient status boards are useful for managing high cognitive workloads and high decision density (Croskerry and Sinclair, 2001; Schenkel, 2000). Patient status boards support situational awareness of patient flow and patient status in support of tasks such as patient hand-off, documentation, teaching, and consulting other medical experts (Patterson et al., 2010; Laxmisan et al., 2007; Bisantz et al., 2010).

Patient status boards have transitioned from dry-erase whiteboards to electronic emergency department information systems (EDIS) (Aronsky et al., 2008; Husk and Waxman, 2004). EDIS implementation has affected ED work practices in unintended ways, particularly with respect to communication among ED staff members and tracking patient progress, indicating that the design of EDIS interfaces have not comprehensively considered the information and communication needs of the end-users (Bisantz et al., 2010; Hertzum and Simonsen, 2013). Recent regulations by the Office of the National Coordinator for Health Information Technology (ONC), Health and Human Services, require vendors to attest to user-centered design processes, and conduct usability studies on final products (ONC, 2015). These recommendations emphasize a need to identify design and evaluation methods that integrate data on the cognitive and information needs of frontline users in the software development process.

Cognitive systems engineering (CSE) provides methods that can

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be employed in a user-centered design process. CSE offers a theoretical approach for the design of information displays that can support and enhance existing work practices by explicitly considering work systems, high level tasks, strategies, socio-technical constraints, and required knowledge and skills (Hajdukiewicz and Burns, 2004; Vicente, 1999). CSE methods have been successfully applied to user-interface design in a wide range of safety critical industries including defense, process control and aviation, as well as for healthcare systems such as neonatal intensive care cardiac nursing and anesthesiology (Naikar et al., 2006; Ahlstrom, 2005; Sharp and Helmicki, 1998; Watson et al., 2004; Yamaguchi and Tanabe, 2000; Seamster et al., 1997; Watson et al., 2000). However, CSE has not been used to design aspects of EDIS displays. Using CSE methods may support design of information displays that provide necessary information more effectively and enabling clinicians and staff to work more efficiently.

This paper presents the results of a usability assessment of novel EDIS display concepts that were designed using CSE methods. This study is part of a larger research program that took a systematic, CSE approach to identifying information needs and then iteratively refining and testing information displays based on those needs. In particular, and based on a work-centered systems design framework, we were interested in identifying high level cognitive requirements that an EDIS system should support, and then designing display elements or areas which supported users in meeting those requirements (Wampler et al., 2006). To accomplish this, our research program 1) performed a CSE work domain analysis of the ED to identify needs for support and related information requirements; 2) used the results to design novel EDIS displays; and 3) evaluated the success of the design in several studies (using multiple objective and subjective methods), including the study we describe here (Guarrera et al., 2013, 2015; Clark et al., 2014).

First, in order to identify information requirements, CSE work domain modeling methods drawn from a well-known theoretical framework - cognitive work analysis (Vicente, 1999) - were used to describe hospital emergency departments. The work domain model consisted of nodes representing high-level system purposes, abstract constraints and functions, processes, and system resources. Next, information requirements related to these model elements were identified and used in an iterative design process involving domain experts (emergency medicine physicians and a nurse) and human factors engineers to create and improve prototype display concepts for a novel EDIS. (See Guarrera et al., 2015 for a complete description of the modeling results and design process) (Guarrera et al., 2015).

The resulting display concepts consist of seven display areas that can be accessed through a main dashboard (Fig. 1a). Together, the displays present information related to management of patient care and patient flow through the ED, with a particular focus on maintaining situational awareness of the ED as well as patient status and facilitating team communication and coordination. The displays were also designed to help users manage constraints related to patient care, such as availability of laboratory and imaging facilities, personnel workloads and bed availability throughout the hospital. Innovative features include: the ability to compare current and historic information regarding patient volumes (Fig. 1b), a quick status graphic which indicates overall ED status across eight variables (Fig. 1c), a timeline representation of patients in the waiting room, coded by triage score and arranged according to a dynamically updating length of wait (Fig. 1d), patient wait times for tests or consultations (Fig. 1e), color coded phases of care (i.e. waiting, in ED but not initially assessed, diagnosis/treatment, treatment/tests completed, and dispositioned) used both as part of a timeline (Fig. 1f) and to code other representations of patients in bed status and staff workload displays (Fig. 1g and h) along with graphic representation of beds in terms of whether or not they are open (Fig. 1g). The displays were implemented using Adobe Flash Builder 4.6(Adobe Flash Builder, 2010).

2. Material and methods

2.1. Approach

A three-phase usability assessment consisting of an EDIS familiarization phase, a task performance phase and an assessment phase was conducted to evaluate the displays in terms of ease of use, utility, and the extent to which the displays support the work-oriented cognitive needs of emergency medicine clinical staff. Rating scales were derived from a work centered, cognitive systems engineering approach previously used to evaluate prototype displays for a complex work system (Truxler et al., 2012), and were tailored specifically to ED tasks and goals identified through the CSE analysis of the ED as described above (Guarrera et al., 2015). Detailed questions related to specific interface elements were included to allow us to understand which specific aspects of the displays were (or were not) rated as useful or usable.

Results from the assessments were designed to test two hypotheses regarding the design of the EDIS:

1) User perceptions regarding cognitive support, usability, and usefulness of the EDIS will be greater than neutral across all goals for cognitive support and ratings for screen displays.
2) User perceptions regarding cognitive support, usability, and usefulness of the EDIS will be consistent across clinician roles.

2.2. Participant recruitment

Eighteen participants with emergency medicine experience were recruited from a large, multi-hospital system. A recruitment e-mail was distributed to ED staff members via institutional e-mail listservs, and staff members could participate on a voluntary basis. Nine physicians/mid-level providers (attending physicians, residents, and physician assistants) and nine nurses participated. This sample size (overall, and per provider group) reflects the practical challenges in recruiting experienced participants for a laboratory study but allowed comparison across nurse and provider categories. A brief survey was given to each participant to ascertain previous experience with an EDIS. Appropriate Institutional Review Board approval was obtained for this study.

2.3. Setting

The evaluations were conducted on an individual basis in a clinical simulation laboratory setting. The prototype displays were shown on a 27" LCD monitor. Participants could interact with the display to navigate among display areas using a standard mouse. Data drawn from a set of scripted (fictitious) patient cases was used as the source data to populate the EDIS displays (Clark et al., 2014). The scripted patient information could be advanced to a new point simulating the passage of time (see Lin et al., 2008 for a description of a similar ED simulation) (Lin et al., 2008).

2.4. EDIS familiarization

Each participant watched a 12-min training video prior to the study. The video presented a voice-over tutorial of the EDIS and explained basic navigation, information content and functionality of each screen. Participants were instructed to use the displays as