A Framework for Managing Cognitive Load in Electronic Medical Record Systems Training

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Sarang Hashemi
Monash University
sarah.hashemi@monash.edu

Frada Burstein
Monash University
frada.burstein@monash.edu

Abstract

Problems associated with Health Information Technology (HIT) involves human and technical factors. Problems involving human factors, however, are found to be ‘significantly more likely’ to harm patients. A human factor contributing to these problems is cognitive load. While the literature provides a wealth of insight on cognitive load in the area of design and use of HIT, little is discussed about cognitive load in the area of training of these technologies as a prerequisite for competent use. This study explores cognitive load in training of a prevalent form of HIT in intensive care – namely, Electronic Medical Record (EMR) systems. In doing so, the study uses cognitive load theory as a lens to explain cognitive load and its effect on learning and offers a framework for the design of the instructional materials of EMR systems to impose less cognitive load to those who are being trained to use these systems.

Keywords

Health information technology, electronic medical record systems, human factors, cognitive load, training, cognitive load theory, instructional design, intensive care unit.

Introduction

The rate of adoption of Health Information Technology (HIT) has been on the rise. Mounting evidence, however, suggests that HIT poses considerable risks to patients (Ash et al., 2004). In a study of all patient safety events associated with England’s national programme for IT between 2005 to 2011, for instance, Magrabi et al. (2015) examined those events against an existing classification of HIT problems and reported that 68% were hazardous to patients. Of those events, 92% related to technical and 8% to human factors. Problems involving human factors, however, were found to be ‘significantly more likely’ to harm patients. In England, these problems were ‘four times as likely’ to harm patients (p. 203). In the U.S., this figure was staggeringly higher – ‘15 time as likely’ (p. 204). These problems were related to human’s interaction with IT. They were attributable to ‘use errors’ in the form of information input or output errors and the contributing ‘socio-technical contextual variables’ such as staffing/training and cognitive load. HITs that are susceptible to ‘use errors’ or ‘socio-technical contextual variables’ are ‘significantly more likely’ to bring about a harmful effect on patients. This susceptibility is particularly pronounced for HITs that aim at providing timely and accurate data for decision-making in life-threatening conditions. A prevalent form of these technologies is Electronic Medical Record (EMR) systems in intensive care environments. In these environments, “EMR is an enabling technology that facilitates and enhances the clinician’s ability to make decisions at the precise point of care” (Sado, 1999, p. 505). Thus, effective use of EMR systems requires competent interaction with these systems especially in intensive care environments where competent interaction with the system can have a life-and-death effect on patients. This is particularly true for newly-adopted EMR systems where intensivists heavily rely on their training to interact with the system for decision-making and intervention.

In this study, we focus on training of EMR systems as a prerequisite for competent interaction and use. We discuss how socio-technical variables such as cognitive load can impair learning and propose a guideline to manage cognitive load during training activities for these systems. In doing so, we subscribe to Cognitive Load Theory (Sweller, 1988) to derive guidelines for the design of instructional materials for EMR systems, and address the question of ‘how can instructional design enhance the learning outcome of EMR systems training?’ This paper reports the conceptual phase of the study.
Cognitive Load and EMR Systems

A contributing element to problems involving human factors is cognitive load. It is a socio-technical variable, which can be defined as “the load imposed on an individual’s working memory by a particular task” (van Gog & Paas, 2012, 599). A closer look at the literature, however, reveals that the association between cognitive load and EMR systems is primarily discussed in areas involving design (Faiola et al., 2015) and use (Shachak et al., 2009). These areas are generally addressed by studies focusing on ‘usability.’ The reason for this can be explained by the prevailing view on usability, which has been increasingly regarded as a deterrent to the adoption of EMR systems (Smelcer et al., 2009). As a result, researchers focused on principles that guide the design and use of these systems, and cognitive load in these areas received close attention. This can be confirmed by a recent review by Zahabi et al. (2015) who identified 46 studies on usability issues associated with EMR systems. Over 28% (13 studies) addressed ‘minimizing cognitive load’ – one of nine usability principles for EMR systems (HIMSS, 2009).

Hence, other areas of EMR systems involving cognitive load are overlooked. Training is one of these areas. The link between cognitive load in education and training has been recognized by cognitive researchers since 1980s, but it has not been discussed in relation to education and training of EMR systems. Training is a prerequisite for competence and is often viewed as a measure of organizational health in different industrial settings (Reason, 1995). In medical settings, it is considered as a means to: reduce adverse event (Kerridge et al., 1998); manage errors (Helmreich, 2000); and, improve clinical care (Patterson et al., 2013). With respect to EMR systems, training is regarded as an ‘important prerequisite’ to implementation (Joukes et al., 2015) as well as a barrier to adoption (Graniëï & Hertzum, 2009) and use (Patterson et al., 2004). A closer look at the literature revealed that few scholars discussed cognitive load in training for EMR systems. One example, in the form of a question for future work, was suggested by Patel & Ozok (2011, p. 688). They asked, “how can we design training to deliver important concepts without causing cognitive overload?” Our study provides the necessary framework to answer the question they posed using a cognitive load theory.

Cognitive Load Theory

Cognitive Load Theory (CLT) provides a framework for understanding cognitive load and its effects on working memory thereby learning of a task. It offers techniques to measure and manage cognitive load and informed research in different domains such as learning (van Merriënboer & Sweller, 2005); performance (La Rochelle et al., 2011); and, medical education (Young et al., 2014). The theory has relevance to the medical domain because the tasks performed by medical professionals integrate multiple elements of information, which cognitively loads their working memory and impairs their learning and performance. CLT is based on human’s cognitive architecture with three subsets of human memory – sensory, working, and long-term memories (Atkinson & Shiffrin, 1968). The sensory memory receives a large amount of information from the human’s sensory system but retains it for a short period (0.25 to 2 seconds) (Mayer, 2010). It processes information but can only hold 7±2 elements of information (Miller, 1956) for a short time (15 to 30 seconds) (Young et al., 2014). The working memory can process only 2 to 4 elements at any given time (Kirschner et al., 2006), which is even lower than the 7±2 elements it holds. The long-term memory, in contrast, is theoretically limitless in storing and retaining information in the form of cognitive schemas – “a cognitive construct that organizes the elements of information according to the manner with which they will be dealt” (Sweller, 1994, 296). Schema helps the individual to form a large amount of information as one ‘chunk’ for later use in the working memory (van Merriënboer & Sweller, 2010). Understanding this architecture has significant implications for medical professionals because the nature of learning tasks often requires holding more than 7±2 elements, processing more than 2 to 4 elements, and retaining this information for more than 15 to 30 seconds.

CLT integrates the cognitive architecture with cognitive load and its impact on working memory. It views cognitive load as “the load imposed on an individual’s working memory by a particular task” (van Gog & Paas, 2012, 599) and distinguishes between intrinsic, extraneous, and germane loads. The intrinsic load is inherent to a task (e.g., the complexity of a learning task). Its level is directly related to the number of or interaction between the elements of information associated with a task. That is, the higher the number of elements or the greater the interaction between them, the higher the level of intrinsic load on the individual’s working memory. The Extraneous load is the load on the working memory that is extrinsic to a task (e.g., distraction). It is closely related to the presence of factors that are unnecessary for learning a task. Various factors such as disproportionate loading of audio and visual channels of the learner can result in a higher level of extraneous load. The Germane load differs from the others and is imposed by mental efforts necessary for learning (e.g., concentration to learning a task and constructing schemas). The lower are the intrinsic and extraneous loads; the higher is the level of germane activities hence increased level of learning. CLT strategies and techniques to address cognitive load are discussed in the following sections in the form of a framework.
A Framework for Managing Cognitive Load

As emphasized by van Merriënboer & Sweller (2005, p. 85), “cognitive load theory aims to develop instructional design guidelines based on a model of human cognitive architecture.” It offers various strategies and techniques to manage cognitive load at the construct level. These strategies and techniques, in the form of design guidelines for education in the medical domain, have been discussed by a) van Merriënboer & Sweller (2010); b) Young et al. (2014); and, c) Leppink & van den Heuvel (2015). Figure 1, below, illustrates these strategies and techniques.

Figure 1. Strategies and Techniques for Managing Cognitive Load at the Construct Level

The upper box, shown in dashed lines, displays the strategies and techniques for managing cognitive load that is imposed by instructional materials. The lower box, also shown in dashed lines, displays the cognitive load that is experienced by trainees. These boxes, along with their components are linked with arrows indicating the application of strategies and techniques to the design of instructional materials at the construct level of cognitive load. This is applicable on the instructional materials that are used in training for EMR systems and to manage the cognitive load that they impose on their trainees (e.g., medical and nursing staff in intensive care environments). This study views these strategies and techniques from a pluralistic perspective and derives guidelines that might apply to the design of instructional materials for EMR systems training. These guidelines, in the form of a framework, for training of EMR systems are shown in Table 1 below.

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<thead>
<tr>
<th>Strategies</th>
<th>Techniques</th>
<th>Descriptions</th>
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</thead>
<tbody>
<tr>
<td>Managing Intrinsic Load</td>
<td>Isolated element</td>
<td>Complex information (information with high level of element interactivity) should be presented initially as isolated elements and gradually as interacting elements.</td>
</tr>
<tr>
<td></td>
<td>Progress from low- to high-physical fidelity</td>
<td>Complex tasks should be performed initially from low-fidelity and gradually progress to high-fidelity (from case descriptions to computer-simulated patients to real patients).</td>
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<tr>
<td></td>
<td>Progress from simple to complex</td>
<td>Information should be presented initially with lower complexity to higher complexity (from lower to higher number of interactions between elements).</td>
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<tr>
<td>Decreasing Extraneous Load</td>
<td>Worked example</td>
<td>Provide the learner with a step-by-step demonstration of the solution to the problem. This will help the learner to study rather than searching for solution to the problem.</td>
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<td>Problem completion</td>
<td>Provide the learner with the partially-completed solution to the problem, and then ask the learner to complete the solution.</td>
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<td></td>
<td>Split attention</td>
<td>Replace the multiple sources of information that are separated in space and time or cannot be understood in isolation with a single and integrated source of information.</td>
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<td></td>
<td>Modality</td>
<td>Present information through multimodal, as opposed to unimodal forms (e.g., both visual and auditory versus only visual or auditory processor).</td>
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<td></td>
<td>Transient information</td>
<td>Present information with high level of complexity with pauses to enable learners to have time to track or memorize the information.</td>
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<tr>
<td></td>
<td>Redundancy</td>
<td>Replacing multiple sources of information that can be understood on their own with only one source.</td>
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### Table 1. Guidelines for Design of Instructional Materials for EMR Systems Training

<table>
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<tbody>
<tr>
<td>Non-specific goals</td>
<td>Replace conventional tasks</td>
<td>Replace conventional tasks with goal-free tasks that provide learners with a non-specific goal.</td>
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<tr>
<td>Contextual interference</td>
<td>Present different versions of a task (A, B, and C) in a blocked order (AAA, BBB, and CCC) rather than random order (BCAACCBBAC).</td>
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<td>Variability</td>
<td>Present a task in a multiple variety that exists in the real world.</td>
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<tr>
<td>Imagination</td>
<td>Encourage learners to imagine/visualize concepts and procedures, as opposed to, asking them to simply study the materials.</td>
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<tr>
<td>Self-explanation</td>
<td>Prompt learners to self-explain the given concepts.</td>
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### Conclusion

As discussed, the literature recognizes the link between cognitive load and EMR systems. However, this link is primarily discussed in ‘design and use’ and not ‘training’ of these systems as a prerequisite for competent use. This study, in contrast, focuses on cognitive load in training for EMR systems with an emphasis on the cognitive load that is imposed by their instructional materials. The study takes a pluralistic approach to the strategies and techniques prevailing in the literature in medical education and extends it to other subsets of the medical domain. It uses an interpretive case study in an intensive care unit with semi-structured interviews derived from the proposed guidelines to explore the views of a cohort consist of the designers of instructional materials; trainers who deliver the materials; and, the trainees who are trained by the materials.

The transferability of the proposed framework for training for other forms of HIT requires empirical testing and scrutiny. Further research is needed to measure the cognitive load that is imposed by the redesigned instructional materials to confirm the effects of this framework on the training of EMR systems and ultimately the other forms of HIT. Subjective methods can be utilized to measure the cognitive load that is experienced by trainees. At the current development stage in cognitive load research, instruments have been devised and tested for subjective measurement of the cognitive load imposed by the instructional materials immediately after the training sessions. A validated instrument to measure cognitive load at the construct level is identified which enables the trainees to self-rate the cognitive load they experienced during the training activities.

Further research is also needed to study the effects of the proposed framework on trainees with different level of expertise. Cognitive load theory also recognizes what it refers to as the ‘expertise reversal effect’. The expertise reversal effect “indicates that principles that work well for novice learners may not work well or may even have negative effects for more experienced learners” (van Merriënboer & Sweller, 2010, p. 88). This effect has been demonstrated for principles such as worked examples (Kalyuga et al., 2001), completion strategy (Renkl & Atkinson, 2003), and split attention (Kalyuga et al., 1998).

From the contribution point of view, this study can be beneficial to both theory and practice. From the theoretical perspective, the study can expand the reach of cognitive load theory into a new subset of medical domain (e.g., EMR systems training). This could result in a more in-depth understanding of cognitive load during the training for EMR systems and how to utilize the theory to manage the cognitive load of trainees. From the practical viewpoint, the study can result in the recommendations for the design of instructional materials in such a way that they impose less cognitive load, and subsequently, enhance the learning outcome of trainees for EMR systems. To best of authors’ knowledge, this study is the first of its kind that applies CLT’s theoretical framework to EMR systems training.

### REFERENCES


