ACIS 2019 Proceedings

Australasian (ACIS)

2019

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Recommended Citation

Hashemi, Sarang; Burstein, Frada; Tan, Kenneth; and Bain, Christopher A., "Addressing Cognitive Load in Training on Electronic Medical Record Systems" (2019). *ACIS 2019 Proceedings*. 56.
https://aisel.aisnet.org/acis2019/56

Addressing Cognitive Load in Training on Electronic Medical Record Systems

Research in Progress

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Abstract

Problems with Health Information Technology (HIT) involve human and technical factors with human factor *significantly more likely* to harm patients. A human factor contributing to these problems is cognitive load – the load imposed on an individual's working memory. While the literature explored cognitive load in areas of design and use of HIT, little is discussed about it in the area of training – a prerequisite for competent use of HIT. This study subscribed to Cognitive Load Theory (CLT) and explored cognitive load in training on Electronic Medical Record (EMR) systems as a prevalent form of HIT in intensive care environments. Designers, trainers, and trainees of instructional materials for EMR systems training in a neonatal intensive care unit were interviewed in an interpretive case study. The preliminary results indicated cognitive load as a recognised phenomenon in EMR systems training but pointed to a lack of awareness of CLT techniques for managing cognitive load.

Keywords: Health information technology, electronic medical record systems, human factors, cognitive load, training.

1 INTRODUCTION

Health Information Technology (HIT) has a rising rate of adoption in recent years. Evidence, however, points at the risks that HIT impose on patients (Ash et al. 2004). Magrabi et al. (2015), in a study of all patient safety events associated with England's national programme for IT between 2005 to 2011, examined all safety events against an existing classification of HIT problems. They reported that 68% of safety events were hazardous to patients. Of those, 8% were related to human factors and 92% to technical factors. Nevertheless, the problems involving human factors were found to be *significantly more likely* to harm patients. In England, these problems were 'four times as likely' to harm patients (p. 203). This figure was staggeringly higher in the United States and Australia – '15 time as likely' (p. 204).

The problems involving human factors were related to human interaction with IT. They were attributable to *use errors* in the form of information input or output errors as well as the contributing *socio-technical contextual variables* such as staffing/training and cognitive load. This observation necessitates a closer look at the forms of HIT that are susceptible to use errors or socio-technical variables as they 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 critical and 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). Effective use of EMR systems, therefore, requires competent interaction with these systems, especially in intensive care environments where competent interaction with such a system can have a life-and-death effect on patients. This is particularly true for a newly-adopted EMR system where intensivists heavily rely on their training to skilfully interact with the system for decision-making and intervention.

This study views training as a prerequisite for competent interaction with and use of EMR systems. In this paper, we focus on the effect of socio-technical variables such as cognitive load on learning in EMR systems training. Using Cognitive Load Theory (Sweller 1988), we derived guidelines for designing instructional materials for EMR systems training, and asked designers, trainers, and trainees of an EMR system training (i) whether they experienced cognitive load in EMR systems training; and, (ii) if they were aware of techniques offered by CLT to manage cognitive load for the design of their instructional materials? This paper reports preliminary findings of the earlier stage of analysis: (i) cognitive load as a recognised phenomenon in EMR system training; and, (ii) a lack of awareness of CLT techniques for managing cognitive load.

2 COGNITIVE LOAD AND EMR SYSTEMS

Cognitive load is viewed as a contributing element to problems involving human factors. It is considered as a socio-technical variable (Magrabi et al. 2015) and can be defined as "the load imposed on an individual's working memory by a particular task" (van Gog & Paas 2012, p. 599). The literature provides a wealth of insight into the association of cognitive load and EMR systems. Shachak et al. (2009), for example, investigated physicians' patterns of EMR use and the underlying cognitive elements involved in resulting errors. They used Cognitive Task Analysis – a method to identify the cognitive skills or mental demands needed to perform a task proficiently (Militello & Hutton 1998) – and reported that clinical tasks such as diagnosing, reasoning, and treating medical conditions imposed the highest level of cognitive load.

A further study conducted by Giri et al. (2012) recognised that sub-optimal design of EMR systems could increase cognitive load and disrupt workflow particularly in ICU environments where the overload of information could lead to inefficiency of care and increase of error. To address this, they developed a novel user interface and introduced it into an existing EMR system in different ICU settings. The novel interface focused on the information needs of ICU providers and prioritised the display of high-value data for assessment and treatment of critically ill patients. They concluded that the novel interface significantly reduced the time spent in their data gathering activities in different intensive care units.

A closer look at the literature, however, revealed that the association between cognitive load and EMR systems are primarily discussed in areas involving *design* and *use*. These areas were generally addressed by 'usability' studies, which can be explained to a large extent, by the views on usability that increasingly regarded it as a deterrent to the adoption of EMR systems (Smelcer et al. 2009). Consequently, researchers shifted their focus on principles that guide the design and use of these systems, and cognitive load in these areas received close attention. A recent literature review by Zahabi et al. (2015) confirmed that. Of 46 studies identified on usability issues associated with EMR systems, over 28% (13 studies) addressed 'minimising cognitive load' – one of nine usability principles for EMR systems (HIMSS 2009). Consequently, other areas involving cognitive load in EMR systems are often overlooked, and *training* is one of these areas.

Training is a prerequisite for competence. It has been considered as a measure of organisational health in different industrial settings (Reason 1995). In medical settings, it has been viewed as a means to improve clinical care (Patterson et al. 2013), manage errors (Helmreich 2000); and reduce adverse events (Kerridge et al. 1998). For EMR systems, training has been regarded as an 'important prerequisite' to implementation (Joukes et al. 2015) as well as a barrier to adoption (Granlien & Hertzum 2009) and use (Patterson et al. 2013). Despite the impairing effect of cognitive load on learning during training and education, a limited number of studies have addressed cognitive load in training for EMR systems (Patel & Ozok 2011). Cognitive Load Theory can help in addressing this issue.

3 COGNITIVE LOAD THEORY

Cognitive Load Theory (CLT) was developed by John Sweller in 1980s (Sweller 1988). This theory offers a framework for understanding cognitive load and its impairing effect on working memory thereby learning. CLT offers different techniques to *manage* and *measure* cognitive load and informed research in different domains such as learning (van Merriënboer & Sweller 2005); performance (La Rochelle et al. 2011); and, increasingly in medical education (Young et al. 2014). CLT has relevance to the medical domain because the tasks involved in this domain requires the medical professionals to integrate multiple elements of information, which can cognitively tax their working memory and impair 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). The working memory 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). It 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). 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* information for more than 15 to 30 seconds.

CLT also integrates the cognitive architecture with cognitive load and discusses its effect on the working memory. It distinguishes between *intrinsic*, *extraneous*, and *germane* loads. The intrinsic load is inherent to a task and 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 is 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). For an enhanced learning outcome, CLT proposes strategies to manage intrinsic load, to reduce extraneous load, and to optimise germane load; and offers techniques to manage cognitive load that is imposed by instructional materials. These strategies and techniques have been used to inform the design of instructional materials for education in the medical domain by (a) van Merriënboer and Sweller (2010), (b) Young et al. (2014), and (c) Leppink and van den Heuvel (2015). Nevertheless, cognitive load theory, despite its relevance to the medical domain, has not been used to inform the training on systems used in this domain. Earlier, we took a pluralist approach to these strategies and techniques and suggested a framework for the design of EMR system training (Hashemi & Burstein 2019). Figure 1 below illustrates this framework.

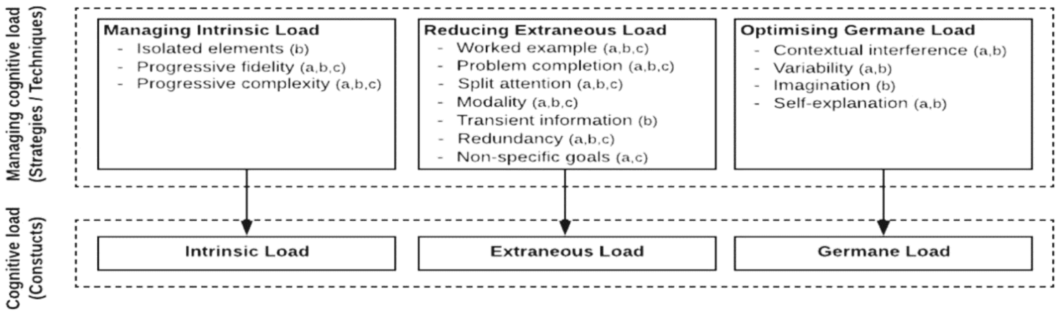

Figure 1: The suggested framework to manage cognitive load in EMR systems training

4 THE DESIGN OF THE STUDY

In designing the study, we first recognised our philosophical assumptions about ontology (reality as socially constructed based on humans' subjective interpretation), epistemology (knowledge can be acquired through human's subjective experience of reality), style of reasoning (inferences about general principles can be made inductively from particular instances), and place of values in research (values are embedded in humans and hence integrated with research and research data). We then aligned these assumptions with our choice of research paradigm (interpretivist), research method (case study research) and research techniques for data collection/analysis (semi-structured interviews / thematic analysis).

We identified individuals with the roles of (i) designers of instructional materials, (ii) trainers who delivered those materials, and (iii) trainees such as doctors and nurses who were trained by the same materials for EMR systems training. We conducted nine interviews with two designers, two trainers, and five trainees (three doctors / two nurses) in a neonatal intensive care unit at a public hospital in Melbourne, Australia which has been using an EMR system, and designing/delivering instructional materials to its staff. The data collection instrument was a piloted semi-structured interview derived from the literature in cognitive load research and CLT strategies and techniques for managing cognitive load. The instrument included 21 questions distributed across three sections. The first section aimed to capture the awareness of cognitive load through six questions. These questions focused on descriptions and experience of cognitive load. The second section was specifically worded to capture the individual's perception (at each role) of CLT techniques known to manage cognitive load through 15 questions. Of those questions, three focused on techniques to managing intrinsic load, six on reducing extraneous load, and four on optimising germane load. The last section focused on the efficacy of the design and delivery of instructional materials and suggestions for improvement through two questions. The application to ethics committees of both the participating organisation and the education provider received approval before the process of data collection. The interview recordings were anonymised and transcribed verbatim. For data analysis, we took a reflexive approach to thematic analysis and adopted the framework suggested by Braun and Clarke (2006) to guide the analytical process using NVivo 12.

5 PRELIMINARY FINDINGS

We observed two preliminary findings in the early stage of analysis: (i) cognitive load as a recognised phenomenon in EMR system training, and (ii) a lack of awareness of CLT techniques for managing cognitive load. The participants showed an in-depth understanding and shared experience of cognitive load. Designers, who were also experienced members of medical and nursing staff, associated cognitive load with (i) tasks (complexity, demand, urgency); (ii) information (volume, sources, access); (iii) interruptions (staff, families, parallel tasks); and, (iv) ability to process and perform under pressure (treatment and intervention). The stated:

> "I think it is by the nature of our job... Patients are very sick, and they require a lot of top activities in order to keep them alive or treat them..., because it is intensive care environment..., these patients can deteriorate and get worse, and then new problems arise." (R01, Designer, Medical staff)
>
> "To me, cognitive load is how much information you take in, process, access, and then to be able to use." (R07, Designer, Nursing staff)

Trainers associated cognitive load with stress by pointing at cognitive load in *training delivery*, whereas trainees mostly associated cognitive load with information overload when showing signs of fatigue:

> "... given that it's a new system you've gotta learn how it works and understand and be able to then demonstrate how it goes. Certainly, that gives you some kind of anxiety." (R02, Trainer, Nursing staff)
>
> "... in a work status, it would more be either when there's a lot happening at the same time, or at the end of a long week for cumulative tiredness ..." (R08, Trainee, Medical staff)
>
> "Having to concentrate really hard. Really concentrate... Really thinking a lot when I've got a lot going on and I'm trying to think about and understand a whole lot of information, I quite often actually close my eyes (R05, Trainee, Nursing staff)

No respondents associated cognitive load with learning in their descriptions. Nonetheless, many recognised the impairing effect of cognitive load on their learning. They commonly pointed at the volume of information and its negative effect on processing that information:

> "... yes, I think so... Actually, if they're presented with a lot of competing demands on their attention..." (R01, Designer, Medical staff)
>
> "Yes, I can understand that. You know, you get caught up in everything therefore you don't take on board what you're being told..." (R02, Trainer, Nursing staff)

> "… when you're absorbing information from, you know, lots of different sources and you're surrounded by a high stress environment…, I think your ability to absorb and retain information would have to be in some way impaired." (R03, Trainee, Medical staff)

Similarly, some respondents also recognised the cognitive load that is imposed by instructional materials. They pointed at a disconnect with contents, and generally attributed it to the complexity of materials or difficulty processing different form of information presented by those materials.

> "…I knew sitting through death by PowerPoint and you've got five lectures in a day …, by the end of the day you're not actually paying any attention or taking anything in." (R08, Trainee, Medical staff)

> "It's like an overload of information… That's why I always find it really important when I am doing any instruction materials to write in different ways. So, you might have one as a written word. People like that. Well this is a pictorial because some people would like pictorial rather than having to read lots of words. (R04, Trainer, Nursing Staff)

Designers viewed this issue differently and stressed on two critical points that have been recognised by CLT. The first point indicated a relationship between intrinsic and germane loads, where an increase in intrinsic load (load inherent to a task) can result in an increased germane load (mental efforts necessary for learning) and enhanced learning outcomes (van Merriënboer & Sweller 2010):

> "I think there is probably a slight increase in cognitive load, but they help the ability to ask questions. And then, … the trainer might be there to help to answer questions." (R01, Designer, Medical staff)

The second point stressed on *steps* in instructional materials. This point has also been recognised by CLT as a technique to reduce extraneous load (load extrinsic to a task) by providing at least one demonstration of the problem-solution path in a *step-by-step* manner rather than asking them to *search for the solution themselves*. This technique is known as 'worked example' (Kalyuga et al. 2001) and is incorporated in our suggested framework (see Figure 1):

> "… you have to understand the person's logic of how they've developed that material, … how they've got [from] one spot to another, and… if the person who's designed it hasn't put absolutely every step in the way… you can't work how you get to the next step." (R07, Designer, Nursing staff)

Nevertheless, we observed that no respondents were aware of techniques for managing the cognitive load imposed by instructional materials. This included all designers and trainers who sounded even surprised when we asked if they knew about techniques that are specifically designed to manage cognitive load imposed by instructional materials. They commonly stated:

> "No, I wasn't aware of that." (R01, Designer, Medical staff)

> "Oh right! No, I didn't know that." (R07, Designer, Nursing staff)

> "Probably not, really." (R02, Trainer, Nursing staff)

> "Not formal ones. No." (R04, Trainer, Nursing staff)

Surprisingly, only one respondent, a trainee, claimed to know about these techniques. The domain that informed the respondent's knowledge is worth considering:

> "Yes, the rest of my family work in *education* [emphasis added]. I've heard about that sort of stuff from them…" (R08, Trainee, Medical staff)

6 DISCUSSION AND CONCLUSIONS

As discussed earlier, the literature recognises the association between cognitive load and EMR systems. Nevertheless, this association is primarily discussed in the areas of *design* and *use* and not necessarily in *training* on the use of these systems. This study focused on training on the use of EMR systems and explored the awareness of cognitive load and techniques to manage cognitive load in this subset of the medical domain. Although the analytical process of this study is at its earlier stage, our preliminary observations indicated cognitive load as a recognised phenomenon in EMR system training in a neonatal intensive care environment. Visiting these environments can be a catalytic experience in understanding the responsibilities of intensivists. In these environments, intensivists are as cognitively loaded as they are physically and emotionally involved when treating a critically-ill neonate. They are also as heavily dependent on their training as they are on their medical knowledge for skilful interaction with systems and effective treatments of patients.

This observation shows the necessity for addressing cognitive load in these environments, be it in the medical education or systems design, use, and training. With respect to systems training, CLT can inform the design of instructional materials to impose less cognitive load and result in enhanced learning outcomes. To do so, it is incumbent upon HIT developers and instructional materials designers to remain informed on the practical implications of CLT in the design of instructional materials and training activities for systems used in the medical domain, particularly those used in intensive care environments.

Another preliminary observation pointed at the lack of awareness of CLT techniques known to manage cognitive load. Despite the small number of designers interviewed, their level of experience and commitment to their work lacked an essential knowledge of these techniques. As previously discussed, cognitive load theory provides a series of strategies and techniques to manage cognitive load at the construct level (intrinsic, extraneous, germane load). These techniques have been used to inform the design of instructional materials in medical education (Young et al. 2014) and can equally benefit the system training in this domain (see, Figure 1). One may argue that education differs from training. We concur but submit that training 'as the acquisition of skills' and education 'as the acquisition of knowledge' (Gallagher et al. 2005) are related and even complementary in this domain. That is, effective treatment of patients, particularly critically-ill patients, is a function of medical knowledge acquired through education as well as system skills acquired through training. Cognitive load theory can inform both equally.

We are cognizant of the limited transferability of this study in training on other forms of HIT. We acknowledge that it requires further empirical scrutiny, particularly in respect of specificity of these techniques to training on other forms of HIT. Also, other studies in different intensive care environments are needed to investigate and confirm cognitive load as a phenomenon in EMR systems training. Additional studies are also needed in measuring the level of cognitive load that is imposed by the instructional materials that are informed by CLT to confirm its effects on the training on EMR systems and ultimately on other forms of HIT. Further studies are also necessary to explore the effects of these materials on trainees with different level of expertise. CLT recognises what it refers to as the *expertise reversal effect* (Kalyuga 2009) and allows for further research on this effect in EMR systems training, which usually involves trainees with different level of expertise in term of literacy in systems as well as knowledge in the medical domain.

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