# Health Information Technology and Cognitive Load

## An Exploratory Study into Electronic Medical Record System Training and Instructional Design

*By*

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**Abstract**

The problems with Health Information Technology (HIT) can involve human or technical factors, with human factors *significantly more likely* to harm patients. One human factor contributing to these problems is *cognitive load,* which is the load imposed on an individual's working memory. While the literature has explored cognitive load in the areas of *design* and *use* of HIT, little has been discussed about cognitive load in the area of *training* as a prerequisite for competent use of HIT. This study focuses on Electronic Medical Record (EMR) systems, as a prevalent form of HIT in intensive care environments, and investigates (i) cognitive load in training on EMR systems; and (ii) the merits of instructional design techniques, known to manage cognitive load, for training on EMR systems.

The study subscribed to Cognitive Load Theory (CLT) as a theoretical lens and adopted an interpretive case study with semi-structured interviews. A total of nine interviews with *actors* with different roles in an EMR system training were conducted. These actors comprised (i) two *Designers* who designed the instructional materials for training on the system; (ii) two *Trainers* who delivered training on the system using these instructional materials; and (iii) five *Trainees* who learned how to use the system using the same materials. All actors were medical and nursing staff at a Neonatal Intensive Care Unit (NICU) at a public hospital in Melbourne, Australia.

The reflexive thematic analysis of the interview data showed that (i) the actors interpreted cognitive load as a *recognised phenomenon* before and during their training; and (ii) they *positively regarded* the suggested instructional techniques as having merit for their EMR system training. The practical implications of the findings point to the actors' *state of mind* when undertaking training and highlight the significance of *awareness* of the instructional techniques for all actors. The theoretical implications of the findings further confirm the relevance of CLT to the medical domain and highlight its merits for a subset in this domain—i.e. *medical system training.* The study contributes rich insight into cognitive load in EMR systems training and how to manage it in training on these systems.

**Keywords:**

Health information technology, electronic medical record system, socio-technical variables, cognitive load, cognitive load theory, instructional design, training.

**Declaration**

This thesis is an original work of my research and contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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**Publications during Enrolment**

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# TABLE OF CONTENTS

## Table of Figures

**List of Tables**

**List of Acronyms**

| | |
|---|---|
| ACIS | Australasian Conference on Information Systems |
| CLT | Cognitive Load Theory |
| CTA | Cognitive Task Analysis |
| EL | Extraneous Load |
| EMR | Electronic Medical Records |
| GL | Germane Load |
| HIT | Health Information Technology |
| ICU | Intensive Care Unit |
| ID | Identification |
| IL | Intrinsic Load |
| IS | Information Systems |
| LTM | Long-term memory |
| MIVA 2.0 | Medical Information Visualization Assistant, v.2 |
| MS | Medical Staff |
| MUHREC | Monash University Human Research Ethics Committee |
| NASA-TLX | NASA Task Load Index |
| NICU | Neonatal Intensive Care Unit |
| NPfIT | National Programme for IT (England) |
| NS | Nursing Staff |
| TA | Thematic Analysis |
| RQ | Research Question |
| SQL | Structured Query Language |
| WM | Working Memory |

# CHAPTER ONE

# INTRODUCTION

This chapter presents the motive for and the purpose of this study. It first describes the research problem identified and the research questions posed. It then presents the approach adopted to answer these questions and the rationale for its adoption. The chapter concludes by outlining the organisation of the thesis.

## 1.1. Overview

Health Information Technology (HIT) can be defined as "the application of information processing involving both computer hardware and software that deals with the storage, retrieval, sharing, and use of healthcare information, data, and knowledge for communication and decision making" (Thompson, 2004, p. 38). These technologies have been indispensable to healthcare services and have resulted in enhanced patient outcomes (Brenner et al., 2016). Nevertheless, mounting evidence points to the considerable risks that HIT holds for patients (Ash et al., 2004; Weiner et al., 2007).

In a study of all patient safety events associated with England's national programme for IT (NPfIT) between 2005 and 2011, Magrabi et al. (2015) examined those safety events against an existing classification of HIT problems and reported that 68% were hazardous to patients. Of those events, 92% were related to problems involving *technical factors* and only 8% to those involving *human factors*. However, problems involving human factors were found to be "significantly more likely" to harm patients (p. 198). In England, these problems were "four times as likely" to harm patients (p. 203). In the United States and Australia, this figure was alarmingly higher; "15 times as likely" (p. 204).

The problems involving human factors, as stated by Magrabi et al. (2015), were related to human interaction with information technology. 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. In other words, HITs that were susceptible to *use errors* or *socio-technical contextual* variables were significantly more likely to bring about a harmful effect on patients. This susceptibility is particularly pronounced for HITs intended to provide timely and accurate data for decision-making in life-threatening conditions.

One of the most widespread forms of HIT is Electronic Medical Record (EMR) systems in Intensive Care Units (ICU). In these units, EMR systems has been viewed as a technology to enhance clinicians' decision-making ability at the point of care (see Sado, 1999). Thus, effective use of EMR systems requires competent interaction with these systems, especially in intensive care environments where the quality of interaction with the system can have a life-or-death effect on patients. This is particularly true for newly adopted EMR systems where intensivists rely heavily on their recent system training to competently interact with the system for decision-making and intervention.

This study concentrates on the socio-technical variables contributing to problems in EMR systems. A critical socio-technical variable that contributes to these problems is *cognitive load*; the load imposed by a particular task on the individual's working memory (van Gog & Paas, 2012). A significant amount of the literature recognises the repercussions of cognitive load on HIT (Magrabi et al., 2011; Zhang et al., 2004). For EMR systems, however, the literature primarily examines cognitive load in areas involving *design* (Faiola et al., 2015; Price et al., 2015) and *use* (Shachak et al., 2009; Manojlovich et al., 2018). Consequently, it often overlooks the effect of cognitive load in other areas. Chief amongst these areas is *training* on EMR systems, which is another socio-technical variable contributing to problems involving human factors.

### 1.2. Research Motivation

Training refers to the *acquisition of skills* (Gallagher et al., 2005); the development of the cognitive or psychomotor ability to perform a task. Although often used interchangeably, training differs from education which refers to the communication or *acquisition of knowledge* (Gallagher et al., 2005); the theoretical or practical understanding of a subject. Training has been long viewed as a measure of organisational health in various industries (Reason, 1995). It has been considered as a means of reducing adverse events (Kerridge et al., 1998); a way of effectively managing errors (Helmreich, 2000); and a method for improving clinical care (Patterson et al., 2013).

For EMR systems, training is regarded as an important prerequisite to implementation (Joukes et al., 2015), and when poorly conducted, as a barrier to use (Terry et al., 2012). However, only a few studies point to cognitive load in EMR systems training. One example, in the form of a question for future work, was suggested by Patel and Ozok (2011), who asked: *"how can we design training to deliver important concepts without causing cognitive overload?"* (p. 688). This question establishes the motive for this study.

## 1.3. Research Questions

This study views training as a prerequisite for *competent interaction* with and *skilful use* of systems. The study (i) explores cognitive load in EMR systems training; and (ii) investigates the merit of instructional design techniques known to manage cognitive load, from the perspectives of actors with different roles in EMR systems training. That is, in what way the actors (i) understand or explain their experience of cognitive load in EMR system training, and (ii) view or consider the instructional design techniques to manage cognitive load in EMR system training. These actors are: *Designers* who design and develop instructional materials for these systems; *Trainers* who train and deliver these materials; and *Trainees* who learn from those materials during training on these systems. All actors also serve as medical and nursing staff at a Neonatal Intensive Care Unit (NICU) at a public hospital in Melbourne, Australia (henceforth, the Participating Organisation). Addressing these two points constitutes the essence of this study's research questions:

> *Research Question 1:*
> *How is cognitive load interpreted in EMR systems training?*
>
> *Research Question 2:*
> *How are instructional design techniques, known to manage cognitive load, regarded by different actors in EMR systems training?*

## 1.4. Research Approach

This exploratory study endeavours to answer the above research questions. To do so, the study adopts an interpretive case study with semi-structured interviews to collect qualitative data from the identified actors at the Participating Organisation.

In designing the study, the author first recognised his philosophical assumptions about ontology (that reality is socially constructed on an individual's subjective interpretation) and epistemology (that knowledge can be acquired through an individual's subjective experience of reality). The author also recognised his assumptions on the style of reasoning (that inferences about general principles can be made inductively from instances) and the place of values in research (that values are embedded in human beings and hence integrated with research and research data). The author then aligned these assumptions with his choice of research paradigm (interpretivist), research method (case study research), and research techniques for data collection (semi-structured interviews) and data analysis (reflexive thematic analysis).

The chosen paradigm for this study is the interpretivist paradigm, which "emphasises natural settings together with individual and group perceptions of events and interactions within those settings" (Williamson & Johanson, 2018, p. 580). As Mingers and Walsham (2010) argue, social sciences, as opposed to natural sciences, are dealing with phenomena that are fundamentally different in nature. Research informed by the interpretivist paradigm approaches these phenomena through their role and effect in social life (Klein & Myers, 1999) and from the perspectives of those involved (Nandhakumar & Jones, 1997). The author believes that the choice of the interpretivist paradigm allows the study to approach the problem from a suitable perspective. It also allows the study to investigate the phenomenon through the perceptions of the individuals involved within their natural settings.

Following this choice of paradigm, the study adopts an interpretive case study as the research method.

Case study research is "an empirical enquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are clearly evident" (Yin, 2003, p. 13). It is appropriate for understanding the dynamics of a phenomenon within a single setting (Eisenhardt, 1989) where the action of individuals in the context is important (Yin, 2014) and the experience of people involved is relevant (Darke et al., 1998). Case study research is inherently flexible enough to lend itself to (i) different paradigms (Klein & Myers, 1999; Orlikowski & Baroudi, 1991; Myers & Klein, 2011); (ii) deductive or inductive designs (Eisenhardt, 1989; Sarker & Lee, 2002; Jones & Karsten, 2008); and (iii) qualitative data through relevant techniques for data collection (Klein & Myers, 1999) and data analysis (Floersch et al., 2010). This flexibility allows the author to (i) situate the adopted method within the chosen paradigm (an interpretive case study); (ii) take an inductive approach to using theory as a lens (cognitive load theory); and adopt a qualitative approach to data collection (semi-structured interviews) and data analysis (reflexive thematic analysis).

As a result, the study investigates the phenomenon of cognitive load in EMR systems training from a social perspective through actors with different roles in an EMR system training within a NICU. In so doing, the study (i) uses semi-structured interviews to elicit meaning from people and to understand those meanings from their perspectives in a flexible manner (Williamson, 2018); and (ii) adopts reflexive thematic analysis (Braun & Clarke, 2006) to identify patterns of meanings and to understand the essence of the data (Morse, 2008). Furthermore, the study takes an inductive stance and uses Cognitive Load Theory (CLT) (Sweller et al., 1998) as a theoretical lens. In doing so, the study uses the theoretical framework of this theory to provide a detailed description of (i) what is cognitive load; (ii) what are the categories of cognitive load; (iii) how to study the effects of cognitive load; and (iv) how to use instructional design techniques to manage cognitive load. This way, the study answers both research questions through (i) the participants' interpretations of cognitive load in an EMR system training, and (ii) their views of instructional design techniques for managing cognitive load during training on an EMR system. The data collection instrument is specifically designed to solicit the actors' views on these points.

The study can be beneficial in both theoretical and practical domains. In theoretical domains, the study will expand the reach of CLT into *medical systems training* as a subset of the medical domain. By applying the theoretical framework of this theory, the study results in a more in-depth understanding of cognitive load in training on EMR systems and how to utilise the theory to manage the cognitive load that is imposed by their instructional materials, particularly in intensive care environments.

In practical domains, the study will address the challenges in designing training for EMR systems without causing an impaired level of cognitive load. By discussing the merits of instructional design techniques, the study recommends a set of techniques to manage different categories of cognitive load while designing and delivering training materials for these systems. To the best of the author's knowledge, this study is one of the first of its kind to address these challenges by applying the theoretical framework of CLT to an EMR system training.

### 1.5. Organisation of the Thesis

The study is presented in five chapters. Following this introductory chapter, Chapter Two describes the research background. It first examines the literature focusing on cognitive load and its association with EMR systems. It then presents CLT as the theoretical lens for the study and continues by discussing human cognitive architecture along with its components, their characteristics, and relationships. The chapter also delineates cognitive load, categories of cognitive load, and their respective effects on the working memory as an integral component of this architecture. It also presents strategies for managing each category of cognitive load and discusses instructional design techniques to achieve those strategies. The chapter concludes by discussing the implications of these techniques for managing cognitive load in EMR systems training.

Chapter Three presents the methodology adopted for the study. In so doing, the chapter first presents the *design* of the study by describing (i) the research paradigm and philosophical assumptions that informed the choice of paradigm; (ii) the research method and the justifications for the adopted method; and (iii) the research techniques for both data collection and data analysis. The chapter then presents the *conduct* of the study by detailing (i) the interviews and associated processes; and (ii) the data analysis and the steps guiding its analytical process. The chapter concludes by summarising the key elements of the design and conduct of the study in a tabular format.

Chapter Four reports the findings of the study. It first provides a brief review of the analytical process from the previous chapter. It then presents the findings from this process in the form of three salient themes as well as three emergent findings from the data. Finally, the chapter discusses these findings and posits them in the extant literature on cognitive load and the broader areas of Information Systems.

Chapter Five concludes the study. The chapter first recapitulates the study and continues by answering the research questions based on its findings. Also, it discusses the implications of these findings on theory and practice and explains the contributions of this study to the body of knowledge. The chapter also discusses the strengths and limitations of the study and concludes by providing recommendations for future work and sketching directions for future research.

# CHAPTER TWO

# RESEARCH BACKGROUND

This chapter describes the research background. It first examines the literature focusing on cognitive load and its association with EMR systems. It then presents CLT as the theoretical lens for the study and continues by discussing human cognitive architecture along with its components, their characteristics, and relationships. The chapter also delineates cognitive load, categories of cognitive load, and their respective effects on the working memory as an integral component of this architecture. It also presents strategies for managing each category of cognitive load and discusses instructional design techniques to achieve those strategies. The chapter concludes by discussing the implications of these techniques for managing cognitive load in EMR systems training.

## 2.1. Overview

As discussed in Chapter One, problems involving human factors are *significantly more likely* to harm patients that those involving technical factors (Magrabi et al., 2015). Problems involving human factors are related to human interaction with information technology, and are attributable to (i) *use error* such as errors in information input and output; and (ii) *socio-technical variables* such as cognitive load; "the load imposed on an individual's working memory by a particular task" (van Gog & Paas, 2012, p. 599). In other words, human interaction with health information technologies that are susceptible to use error or socio-technical variables is significantly more likely to bring about a harmful effect on patients.

A widespread form of these technologies is EMR systems in intensive care environments. In these environments, EMR systems act as "an enabling technology that facilitates and enhances the clinician's ability to make decisions at the precise point of care" (Sado, 1999, p. 505). These systems hold an abundance of clinical data (Ellsworth et al., 2014; Palma et al., 2012) and competent interaction with them is essential to produce error-free data which is pivotal to intensivists' decision-making and intervention. The stressful nature of the intensivists' work (Embriaco et al., 2007), and consequently, their susceptibility to problems involving human factors necessitate a closer examination of factors contributing to these problems. This study concentrates on cognitive load and seeks to obtain an in-depth understanding of its association with EMR systems. What follows is a review of the literature that examines the association between cognitive load and EMR systems.

## 2.2. Cognitive Load and EMR Systems

A comprehensive literature review was conducted to understand the association between cognitive load and EMR systems. PubMed, MEDLINE, CINAHL Plus, and Embase were used as the databases to identify the relevant research published since 2000. The submitted search queries consisted of *'electronic medical record'* OR *'emr'* AND *'cognitive load'* for all search fields. The inclusion criteria covered relevant studies reported in the English language that discussed both cognitive load and EMR systems. In total, the query returned 28 studies. After scanning, thirteen studies (46%) were identified as duplicate hence discarded. The remaining fifteen studies (54%) were analysed in detail. The analysis revealed two interesting points. First, most studies (60%) recognised the association between cognitive load and EMR systems. Second, they did so in the areas involving the *use* and *design* of these systems (22% and 78%, respectively). Table 1 illustrates these studies and their association of cognitive load with EMR systems. These studies are sorted by the *association type* followed by the *publication year*.

Table 1. The literature on association between cognitive load and EMR systems

| No. | Author | Title | Database* | Association Type (CL – EMR syst.) |
|---|---|---|---|---|
| 1 | Shachak et al. (2009) | Primary care physicians' use of an electronic medical record system: A cognitive task analysis | a, b, d | Discussed *(Use)* |
| 2 | Manojlovich et al. (2018) | Why don't we talk about catheters? Characterizing physician-nurse communication barriers to appropriate catheter use discussions | d | Discussed *(Use)* |
| 3 | Ahmed et al. (2011) | The effect of two different electronic health record user interfaces on intensive care provider task load, errors of cognition, and performance | d | Discussed *(Design)* |
| 4 | Giri et al. (2012) | Using information technology to reduce time spent data gathering in the intensive care unit | d | Discussed *(Design)* |
| 5 | Price et al. (2015) | Lead user design: Medication management in electronic medical records | a, b, d | Discussed *(Design)* |

| No. | Author | Title | Database* | Association Type (CL – EMR syst.) |
|---|---|---|---|---|
| 6 | Faiola et al. (2015) | Supporting clinical cognition: A human-centered approach to a novel ICU information visualization dashboard | a, b, c, d, | Discussed *(Design)* |
| 7 | Zahabi et al. (2015) | Usability and safety in electronic medical records interface design: A review of recent literature and guideline formulation | a, b, c, d | Discussed *(Design)* |
| 8 | Bowen et al. (2017) | A user-centered glucose-insulin data display for the inpatient setting | a, b, c, d | Discussed *(Design)* |
| 9 | Al Ghalayini et al. (2018) | Too much or too little? Investigating the usability of high and low data displays of the same electronic medical record | a | Discussed *(Design)* |
| 10 | Borycki and Lemieux-Charles (2008) | Does a hybrid electronic-paper environment impact on health professional information seeking? | d | Not discussed |
| 11 | Agarwal et al. (2013) | A study to evaluate emergency provider efficiency and cognitive load using different methods of computerized physician medication order entry | d | Not discussed |
| 12 | Filho et al. (2013) | 3D visualization environment for analysis of telehealth indicators in public health | d | Not discussed |
| 13 | Adams et al. (2017) | CogPod: Patient safety enhancement and cognitive labour | d | Not discussed |
| 14 | Olson et al. (2017) | Human factors affect the time to initiation of CPR in paediatric ICUs | d | Not discussed |
| 15 | Burner et al. (2017) | Development of a standardized response team for massive haemorrhage events outside of an operating room setting | d | Not discussed |

* a: PubMed, b: MEDLINE, c: CINAHL Plus, d: Embase

In terms of *use*, two areas were examined. These comprised (i) pattern of use; and (ii) communication barrier. Shachak et al. (2009) investigated physicians' *pattern of use* of EMR systems and the cognitive element involved in resulting errors and doctor-patient communication. Using Cognitive Task Analysis (CTA), a method of identifying the cognitive skills or mental demands needed to perform a task proficiently (Militello & Hutton, 1998), they interviewed and observed 25 primary care physicians. Their results indicated that clinical tasks, such as diagnosis, reasoning and treatment, imposed the highest level of cognitive load. Nevertheless, the results pointed to a perceived reduction in cognitive load while using EMR systems. This was attributed to the "comprehensiveness, organization, and readability of data" (p. 341) in these systems due to reduction in both "need to recall information" and "difficulty of reading handwriting" (p. 343). The results also showed that most respondents believed that using EMR systems induced medical errors (>60%) and disturbed communication with patients (92%).

Manojlovich et al. (2018) investigated *communication barriers* between physicians and nurses and their effects on indwelling catheters. They interviewed 21 participants including physicians and nurses and found that these communication barriers were created by organisational complexity, which through misalignment of physicians' and nurses' workflows, made it difficult for nurses attending rounds to discuss catheter use. The communication barriers were related to both *social complexity* (e.g., the poor relationship between physicians and nurses, differing priorities, and communication silos) and *cognitive complexity* (e.g., the cognitive load imposed on communicators in understanding and conveying the message). The difficulty associated with locating information in EMR systems in order to decide on catheter use; and the uncoordinated use of both paper and electronic medical records to record and retrieve information about catheter use were found to contribute to the cognitive complexity and the cognitive load imposed on communicators.

In terms of *design*, four areas were examined. These covered (i) information overload; (ii) usability; (iii) visual clarity; and (iv) data display. Ahmed et al. (2011) focused on *information overload* and its overwhelming effect on human cognitive capacity. They believed that data organisation and presentation influenced the user's ability to synthesise the data into a meaningful message. Using a human-centred approach, they developed a novel user interface for an EMR system to *prioritise the display of high-value data* to ICU providers. They compared this interface with a standard EMR system environment in terms of the task load and error of cognition associated with filtering, extracting, and using patient data. Using NASA TLX (Hart & Staveland, 1988), the results of 160 patient-provider encounters indicated the novel interface contributed significantly to reducing (i) task load; (ii) time to task completion (ii); and (iii) the number of errors of cognition associated with the identification and use of relevant patient data.

In another experiment, Giri et al. (2012) compared the same interface developed by Ahmed et al. (2011) in four ICUs and measured its impact on their workflow during morning rounds. They highlighted 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 an increase in errors. The results from direct field observation of 38 clinicians on a round of 180 patients showed that this interface reduced the time spent in data gathering activities. This figure was significantly lower in the surgical ICU (from 16 to 10.5 minute per patient) and marginally lower in the medical (14.9 vs 12.3) and mixed ICUs (11.4 vs 10.8).

Price et al. (2015) also focused on design. They focused on *usability* and user experience issues with EMR systems and utilised the lead user method in combination with a safety engineering review to discover an innovative design for the medication management module in EMR systems. In doing so, they recruited eight lead users with relevant expertise who prototyped and validated eight separate module designs. The resulting design ideas focused on (i) quality; (ii) efficiency; (iii) safety; (iv) reducing cognitive load; and (iv) improving communication for these systems.

Another study that focused on design was carried out by Faiola et al. (2015). They stressed that the advancements in ICU technologies such as EMR systems are yet to address the *visual clarity* of the patient data to reduce cognitive load, mainly, during clinical decision-making. In response, they took a human-centred approach and developed a decision-support tool (MIVA 2.0). They described this tool as an EMR visualisation dashboard to support rapid analysis of real-time clinical data-trends to reduce cognitive load. This dashboard used a "visualisation engine to deliver multivariate biometric data by transforming it into temporal resolutions. The result [was] a spatial organisation of multiple datasets that allow rapid analysis and interpretation of trends" (p. 561). They sampled twelve clinicians with experience in intensive care or emergency environments to compare the design with the paper medical charts used in intensive care environments. They found that their design could potentially reduce cognitive load and increase the speed and accuracy of decision-making.

Bowen et al. (2017) also focused on the *display of data*. They recognised that existing data displays are not optimised to support insulin management. They argued that the management of insulindependent diabetes is a complex task that requires clinicians to cognitively process information across different domains and locations in an EMR environment. To address this, they designed a set of user-centred displays to simplify data presentation for treatment decisions to (i) enhance the clinician's ability to optimise insulin dosing; and (ii) decrease cognitive load and error rates. They argued that "if related variables required for management of diabetic patients are well represented externally via a relational data display harnessing principle of distributed cognition, then the clinician tasked with managing glycaemic management will have less cognitive load and fewer potential interruptions from information foraging, which may lower or eliminate associated cognitive costs" (pp. 687-688).

Similar to Bowen et al. (2017), Al Ghalayini et al. (2018) also focused on the display of data. They hypothesised, however, that high data density in EMR systems might not be a usability issue, provided that the data is *task-relevant* and *well-organised*. To test this hypothesis, they asked thirteen physicians to examine a series of tasks using two versions of the same EMR system shown in the original and redesigned display. The original display showed all display items in different tabs, whereas the redesigned display grouped them logically in one tab. They used different measures to assess both displays against different dimensions of usability, namely efficiency; effectiveness; and satisfaction. The results supported their hypothesis, particularly for cognitive efficiency, where all usability measures indicated that the redesigned display led to lower cognitive load. They concluded by highlighting the role of good display organisation to mitigate the effects of high data density, as well as the importance of assessing cognitive load as part of usability studies.

As demonstrated, the associations between cognitive load and EMR systems are primarily discussed in relation to use and design. These areas are generally addressed by studies focusing on usability—the effectiveness, efficiency, and satisfaction with which users can achieve a set of tasks in a particular environment (ISO, 2018). This can be explained, to a significant extent, by the prevailing view on usability, which has been increasingly regarded as a *deterrent* to adopting EMR systems (Smelcer et al., 2009). Accordingly, researchers shifted their focus to principles that guided 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) confirms this. Of the 50 studies identified on usability issues associated with EMR systems, 13 studies (over 26%) addressed what is known as *minimising cognitive load*—one of the nine usability principles for EMR systems (HIMSS, 2009).

However, other areas involving cognitive load in EMR systems remained under-researched. One area in which cognitive load plays a significant role is *training*; the acquisition of skills to perform a task (Gallagher et al., 2005). With respect to EMR systems, training is viewed as an important prerequisite to implementation (Joukes et al., 2015); and when inadequately provided, as a barrier to adoption (Granlien & Hertzum, 2009); a barrier to use (Terry et al., 2012); and negatively affecting the perceived ease of use (Al-Nassar et al., 2011).

Evidence, however, shows that training can be impaired by cognitive load (Paas, 1992; van Merriënboer et al., 2002; Sewell et al., 2019). Nevertheless, despite the importance of training on EMR systems; and the impairing effects of cognitive load in training, only a few studies have identified cognitive load in training on these systems as an area for further research. An example can be found in the study conducted by Patel and Ozok (2011) who posed a question for future work: "how can we design training to deliver important concepts without causing cognitive overload?" (p. 688). CLT (Sweller, 1988) provides the necessary framework to address questions of this nature and to inform instructional design for EMR systems training. The following section discusses this theory in detail.

## 2.3. Cognitive Load Theory

Cognitive load is the load imposed by a task (e.g., a learning task) on the individual's working memory (van Gog & Paas, 2012). The learning tasks are commonly guided by instructions and learning the task is closely related to the cognitive requirements of processing these instructions. Processing instructions, however, often involves cognitive requirements that surpass the working memory resources, resulting in cognitive overload and impaired learning. This is the central tenet upon which

CLT is built. That is, learning is inhibited when the information processing load exceeds the working memory capacity (Plass et al., 2010). Accordingly, CLT focuses on instructional design based on human cognitive architecture (see Section 2.3.1) (van Merriënboer & Sweller, 2005) to best utilise the working memory capacity (Clark et al., 2011) to manage cognitive load and thereby facilitate learning (Young et al., 2014).

CLT originated in the 1980s through the work of John Sweller and colleagues. A full description of the theory was first given by Sweller (1988). Over a decade later, an updated description of the theory (Sweller et al., 1998) was developed by a group of researchers in the University of New South Wales in Australia and the University of Twente in the Netherlands (see Sweller et al., 2019). Soon after, CLT became internationally recognised as one of the most popular theories in instructional design and educational psychology (Sweller et al., 2019). It has informed research in various domains such as learning (van Merriënboer & Sweller, 2005); performance (La Rochelle et al., 2011) and, increasingly, medical education (van Merriënboer & Sweller, 2010; Young et al., 2014; Leppink & van den Heuvel, 2015). CLT has relevance in the medical domain because the tasks in this domain require the integration of multiple sources of information, which can cognitively load medical professionals, impacting their learning and subsequently, performance.

### 2.3.1. Human Cognitive Architecture

CLT explains how *the load of processing information* influences an individual's ability to process that information (Sweller et al., 2019). In so doing, CLT focuses on human cognition and the architecture of its components, their characteristics, and relationships. This architecture is referred to as Human Cognitive Architecture with three components comprising the *sensory memory*, *working memory*, and *long-term memory* (Atkinson & Shiffrin, 1968).

The sensory memory receives a large amount of information from the human sensory system (e.g., in the form of images through the eyes or sounds through the ears) but *retains* it for 25 to 2000 milliseconds (Mayer, 2010). The working memory (WM), by way of attention, receives the information from the sensory memory. However, when dealing with novel information, WM *holds* only 7±2 elements of information (Miller, 1956) for 15 to 30 seconds (Young et al., 2014). WM *processes* only 2 to 4 elements at any given time (Kirschner et al., 2006), and rearranges these elements into a schema; "a cognitive construct that organises the elements of information according to the manner with which they will be dealt" (Sweller, 1994, p. 296). The long-term memory (LTM), in contrast, is theoretically limitless in storing information in the form of a schema. Schemas form a large number of information elements into one 'chunk' of organised and relevant information (van Merriënboer & Sweller, 2010). As a result, when retrieved, the WM can process a complex schema (i.e. with numerous elements) as one element of information.

A crucial aspect of human cognitive architecture involves the relationships between these components. Despite its link to both sensory and long-term memories, WM functions differently when dealing with information from each component. That is, when the information is novel and sourced externally by sensory memory, WM is limited in capacity and duration. This limitation, however, effectively disappears when the information is internally sourced from LTM (Sweller et al., 2019). The reason for this lies in the information stored in LTM—schemas of organised and relevant information—which can be processed in WM as a single element of information. Figure 1 illustrates human cognitive architecture.

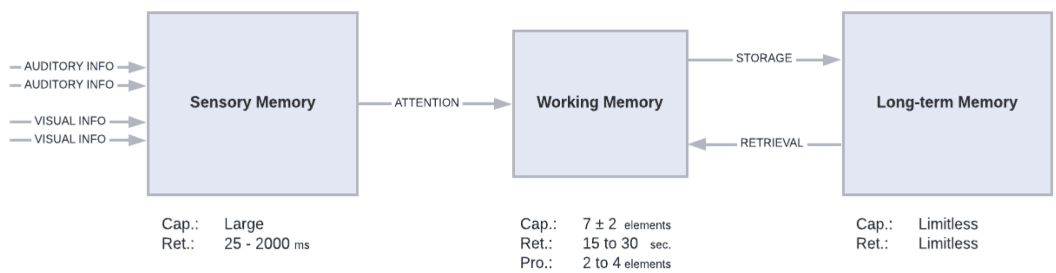


Figure 1. Human cognitive architecture

Understanding this architecture is crucial for two reasons. First, it helps us understand the relations between WM and LTM and their roles in learning. The WM is limited when processing novel information and acts as a *bottleneck* to learning (Mayer, 2010). LTM, however, has unlimited capacity to store schemas and helps WM retrieve those schemas for integration, resulting in more extensive and more complex schemas, a process known as *activation of prior knowledge* (Clark et al., 2011). Second, it helps recognise the function of instructional design and its effects on learning. The primary function of instructions is to help learners accumulate information in LTM. In doing so, instructions should consider the limitations of WM when presenting novel information to learners. This is particularly important for learners in medical domains because in this domain learning often involves information that requires *holding* more than 7±2 elements, *processing* more than 2 to 4 elements, and *retraining* information for more than 15 to 30 seconds.

### 2.3.2. Categories of Cognitive Load

CLT identifies three categories of cognitive load and describes their effects on WM (Chandler & Sweller, 1991). These categories comprise *intrinsic*, *extraneous*, and *germane* cognitive load, and can be imposed by instructional materials for a learning task (Sweller, 2010).

#### *2.3.2.1. Intrinsic Cognitive Load*

The intrinsic cognitive load is inherent to instructions and can be generated by (i) information complexity; or (ii) expertise level. Information complexity is related to *instructions* and refers to the number of information elements or the extent to which those elements interact with one another. This is also referred to as *element interactivity*.

The intrinsic load is positively related to information complexity. That is, the higher the number of information elements or the greater their interconnection, the higher the intrinsic load of instructions for a learning task. The expertise level, in contrast, is related to *learners* and refers to the availability or automation of schemas. The intrinsic load is negatively related to expertise level. That is, the more a learner possesses schema in a relevant domain, the lower his/her intrinsic load. Either way, a limited

WM can inhibit the learner from assimilating multiple information elements simultaneously (Sweller & Chandler, 1994). For that reason, the intrinsic load should be managed either through instructional design or expertise development.

#### *2.3.2.2. Extraneous Cognitive Load*

The extraneous load, on the other hand, is extrinsic to instructions and does not contribute to learning. It is closely related to the presence of factors that are unnecessary for learning a task. Several factors can increase the extraneous load. For example, disproportionate load on the visual processor of WM (e.g., presenting numerous slides) without appropriate support for its auditory processor (e.g., insufficient verbal explanations of each slide) can impose a higher level of extraneous load on learners. Similarly, misaligned loading of the audio-visual processors can also increase the extraneous load. Presenting visual information (e.g., a diagram in a slide) accompanied with auditory but irrelevant information (e.g., explanation about a diagram other than the one presented in the slide) can also impose an extraneous load.

In a similar manner, factors such as distractions (e.g., interruptions during a learning task) or distribution of information elements across time and space (e.g., some explanations about the diagram in one slide and some in another slide) can also increase the extraneous load. Like the intrinsic load, the extraneous load impairs learning but can be controlled through instructional design. Nevertheless, the beneficial effect of reducing extraneous load can be demonstrated when instructions impose high intrinsic load (Sweller, 1994).

#### *2.3.2.3. Germane Cognitive Load*

The germane load differs from the other categories. It is associated with the learner's cognitive activities contributing to learning such as concentration devoted to learning, schema building and automation. These cognitive activities can be generated by the learner or optimised by the instructional features of the learning task. The higher the germane activity, the better the learning outcome. Figure 2(a-d), below, illustrates categories of cognitive load at different levels and their effect on the working memory. Note the additive relationship between the intrinsic and extraneous cognitive load on the limited capacity of the WM, which lowers germane activities and impairs learning.

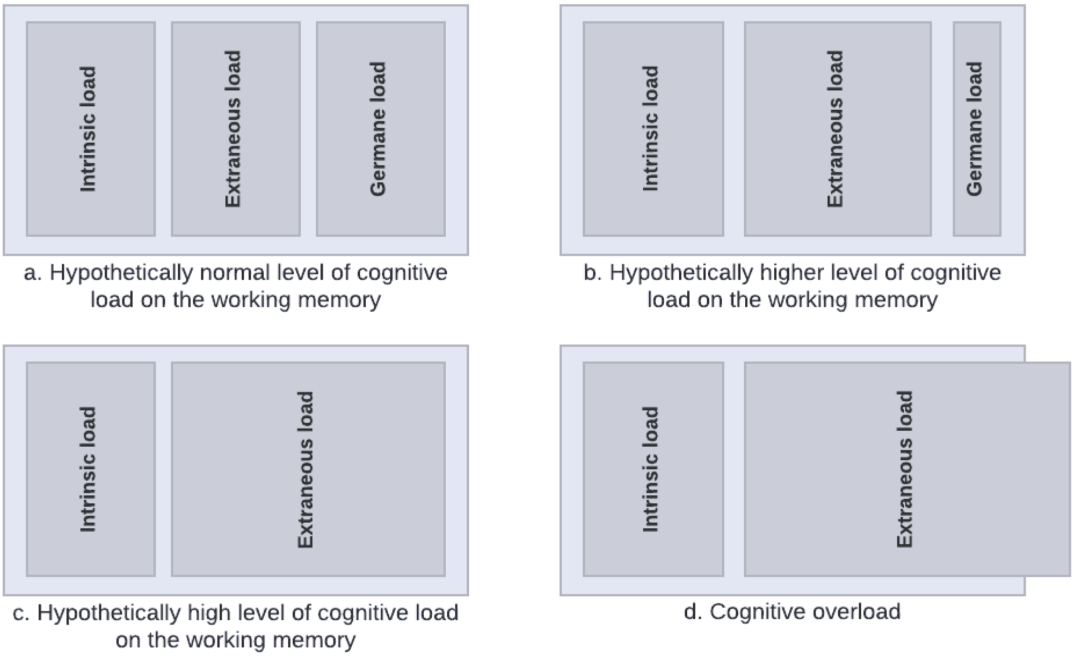


Figure 2. Cognitive load and working memory

### 2.3.3. Strategies for Managing Cognitive Load

As emphasised by van Merriënboer and Sweller (2005), CLT develops instructional guidelines based on human cognitive architecture. In this architecture, the WM limitation in processing information acts as a bottleneck (Mayer, 2010) in learning novel information (Antonenko et al., 2010). CLT provides a framework through which instructional materials can be designed so that this limitation is addressed adequately. It contends that learning can be facilitated by regulating the load on WM through three strategies: (i) reducing extraneous load; (ii) managing intrinsic load; and (iii) optimising germane load (Young et al., 2014). These strategies can be achieved by the following instructional design techniques aimed at each category of cognitive load.

### 2.3.4. Techniques for Reducing Extraneous Load

#### *2.3.4.1. Worked Example*

This technique focuses on the *problem-solution path*. It adopts a *step-by-step* approach to provide a solution to a problem (Sweller & Cooper, 1985). Unlike conventional approaches, which typically ask learners to search for the solution themselves, *worked examples* lead learners to the solution through a series of steps. In other words, they provide learners with a problem-solution model to "study and emulate" (Atkinson et al., 2000, p. 182), which can be stored in their long-term memory as a "problem-solving schema" (Sweller et al., 2011a, p. 99). This way, learners use their WM to learn—rather than search for—the solution steps. As a result, they avoid the extraneous load imposed by processing information elements that are unnecessary to learning. The *Worked Example effect* was first reported by Sweller and Cooper (1985). This effect takes place only if learners experience lower extraneous load and better performance on ensuing problems when studying worked examples rather than solving equivalent problems (Sweller et al., 2011a). The effect can be influenced by the characteristics of *instructions* (e.g., the manners of presenting information) and *learners* (e.g., the expertise level of intended learners). The techniques described in the following pages explain the ways instructions should be presented to learners with different level of expertise. These techniques apply to worked examples directly and should be considered in their design.

#### *2.3.4.2. Problem Completion*

Like Worked Example, *Problem Completion* also focuses on the *problem-solution path*. This technique also provides a step-by-step solution to a problem, but in so doing, it provides *partially-filled examples* for learners to complete (Clark et al., 2011). In other words, problem completions are worked examples which are partially completed for learners to fully complete. In the late 1980s, van Merriënboer and Krammer (1987) developed this technique to address an initial concern about worked examples resulting in passive, rather than active learning (Sweller et al., 2011a, p. 105). Problem Completion addresses this concern by requiring learners to complete steps leading to the solution. This way, learners attend to key information elements in an example and study them in sufficient depth, resulting in more active learning.

#### *2.3.4.3. Split-attention*

This technique concentrates on *sources* of information. It replaces multiple sources of information – distributed spatially or temporally and unintelligible in isolation – with a *single, integrated or synchronised* source (van Merriënboer & Sweller, 2010). For instance, presenting a diagram and the associated description separately (e.g., spatially in different slides) requires learners to *mentally integrate* these two sources of information that essential to learning (Sweller et al., 2019) because they refer to each other. In such cases, the learner must switch from one source (e.g., diagram in one slide) to another (e.g., description in another slide). As a result, the learner must retain information about the diagram in WM, while searching or processing the description. This way, WM resources are diverted from forming schema to dealing with extraneous load (Sweller et al., 2011a). This is an unnecessary process and can be avoided simply by integrating these sources (e.g., description under diagram in one slide). *The Split-attention effect* occurs if the integrated or synchronised instructions results in better learning outcomes compared to split-source instructions. The split-attention effect was first reported by Tarmizi and Sweller (1988) and must be considered while designing effective worked examples (see Ward & Sweller, 1990).

#### *2.3.4.4. Modality*

This technique focuses on the *mode* of presenting information. It is based on the premise that WM has partially-independent processors for auditory and visual information (Baddeley, 1992), processing more information when combined (Sweller et al., 2011a). Accordingly, rather than presenting information *unimodally* (i.e. engaging either processor) to learners, this technique presents information *multimodally* (i.e. engaging both processors) (van Merriënboer & Sweller, 2010). As a result, multimodal presentations offload information from a single processor, which reduces extraneous load and avails WM resources for germane processes (Harskamp et al., 2007). The *Modality effect* occurs if multimodal presentations of information are superior to unimodal ones. Mousavi et al. (1995) were the first to demonstrate this effect and found the instructional benefits of presenting information across modality. They compared a diagram integrated with textual descriptions (e.g., visual only) with the same diagram integrated with verbal descriptions (e.g., visual/auditory) and found multimodal presentation superior. Nevertheless, to ensure the superiority of multimodal presentation, certain conditions must be met: (i) the visual and auditory sources of information must be unintelligible in isolation; (ii) the element interactivity of information must be high; and (iii) the auditory component must be sufficiently short. The latter is due to the transiency of auditory information (Leahy & Sweller, 2011).

#### *2.3.4.5. Transient Information*

This technique focuses on the *transiency* of information. *Transient information* (e.g., verbal instructions) quickly disappears. Consequently, learners need to actively retain information in their WM for later processing (Sweller et al., 2011a). In contrast, non-transient information (e.g., written instructions) remains available and allows learners to revisit that information when necessary. Accordingly, this technique replaces transient with *non-transient forms* of presenting information to ensure its availability. This way, learners avoid extraneous load because they do not have to "use a mental rehearsal strategy to keep information alive in working memory before it dissipates" (Sweller et al., 2011a, p. 220). Leahy and Sweller (2011) were the first to report this effect when they explored the modality of presenting information. They demonstrated that the multimodal presentation of information (e.g., visual/auditory instructions) could have a limited effect when the auditory portion of instructions was longer and hence more transient.

#### *2.3.4.6. Redundancy*

*Redundancy* also focuses on *sources* of information. The difference, however, is *whether* these sources are essential to learning. In Split-attention, the sources are all essential to learning. However, they are split and hence less intelligible in isolation. Learners must mentally integrate these split sources, hence experiencing extraneous load. In redundancy, by contrast, these sources are self-contained and intelligible on their own. As a result, they may contain superfluous information unnecessary for learning. In such cases, learners have to mentally integrate these sources to discover that some information is indeed identical (Sweller et al., 2019). Such information, which is not essential to learning, is classified as "redundant" in CLT (Sweller et al., 2011a, p. 142) and should be omitted (Chandler & Sweller, 1991, p. 330). Accordingly, this technique replaces multiple sources of redundant information with *a single self-explanatory* source. Chandler and Sweller (1991) were the first to report the *Redundancy effect*, which occurs when sources with redundant information result in less learning that those without redundant information.

### 2.3.5. Techniques for Managing Intrinsic Load

#### *2.3.5.1. Isolated Elements*

This technique focuses on the *elements* of information. Instructions often contain complex information involving multiple interacting elements. These elements cannot be simultaneously processed in WM without causing high intrinsic load. Sequencing instructions can prevent this effect. Accordingly, instead of presenting complex information covering all elements and their interactions, this technique first presents *each element*—i.e. in an isolated, non-interacting manner. Once the learner has processed these elements and stored them in long-term memory, then all elements and their interactions are presented. As a result, learners can first build partial schemas (e.g., without processing all interacting elements), and then convert them to full schemas (e.g., without experiencing high intrinsic load associated with processing all interacting elements). Pollock et al. (2002) were the first to demonstrate the instructional benefits of this technique. Learners who were first presented with isolated elements could easily learn and store those elements. As a result, once presented with the complete information, they only had to learn how to integrate those elements, and thereby assimilate the entire information (Sweller et al., 2019).

#### *2.3.5.2. Low- to high-physical fidelity progression*

The term *fidelity* describes the *reality of experience*. The physical fidelity, as defined by Maran and Glavin (2003), is "the degree to which the training device or environment replicates the physical characteristics of the real task" (p. 23). This technique allows the interacting elements in a simulated scenario to increase progressively from low to high. In diagnosing patients, for instance, learners can start with textual problem descriptions (low fidelity); continue with simulated patients (medium fidelity); and end with real patients during the internship (high fidelity) (van Merriënboer & Sweller, 2010). This technique is particularly helpful to novice learners because high-fidelity tasks often provide too many "seductive details" which can impose cognitive overload and impede learning (Dankbaar et al., 2016, p. 506).

#### *2.3.5.3. Simple-to-complex progression*

This technique has a similar effect to Isolated Elements. Instead of presenting a learning task in its full complexity, it allows learners to practice a simpler version of a task and progress to a more complex version (van Merriënboer et al., 2003). Sequencing the task as a whole allows learners to develop a *holistic view* of the task and to integrate and coordinate the required skills to perform the task from the earlier stage of training (van Merriënboer et al., 2003).

### 2.3.6. Techniques for Optimising Germane Load

#### *2.3.6.1. Variability*

This technique focuses on the *variety* of a task. According to van Merriënboer and Sweller (2005), instructions with high variability ensure that a task is practised "under conditions that require the performance of different variants of the task across problem situations" (p. 161). This, in turn, encourages learners to construct schema because it increases the probability of (i) identifying similar features; and (ii) distinguishing relevant ones (van Merriënboer & Sweller, 2010). Accordingly, this technique presents learners with *a series of tasks in different variations*, rather than presenting those with similar surface features only (Sweller et al., 2019). High variability tasks involve more element interactivity and yield higher intrinsic load. However, when the intrinsic load does not exceed WM capacity, learning with high variability tasks improves (Likourezos et al., 2019). Paas and van Merriënboer (1994) were the first to report the *Variability effect*, which occurs when high variability tasks result in enhanced learning, compared to those with low variability. This effect is achievable when instructions first reduce the extraneous load (e.g., through worked examples) and continue with optimising germane load (e.g., using high variability examples).

#### *2.3.6.2. Imagination*

This technique focuses on *mental practice*. Mental practice can be described as the individual's *introspective or covert rehearsal* for preforming a task (Beasley, 1979, cited in Cooper et al., 2001). Evidence indicates that mental practice, or imagining a task, improves task performance (see Ericsson & Charness, 1994). It can also be beneficial to tasks that are predominantly cognitive in nature (Cooper et al., 2001). That being so, this technique encourages learners to engage in imagining or mentally rehearsing, rather than only studying, a given task (Cooper et al., 2001), or the concepts or procedures involved (Leahy & Sweller, 2004). This way, learners engage more in germane processes which, in turn, enhances learning. Nevertheless, this technique is unlikely to be beneficial for novice learners because they lack the prerequisite schemas to be able to imagine a task adequately. Once learners have developed enough expertise and possessed the necessary schemas to imagine a task in an adequate manner, then incorporating this technique into training can be beneficial (Sweller et al., 2019).

#### *2.3.6.3. Self-explanation*

Like Imagination, this technique also concentrates on *mental practice*. Evidence shows that explaining a concept or procedure to oneself is beneficial to learning (Chi et al., 1989). This is because learners incorporate their prior knowledge when self-explaining a concept or procedure (van Merriënboer & Sweller, 2010), causing more germane processes. As a result, as demonstrated by Chi et al. (1989), leaners could elaborate on applicability; relate learning to domain; and monitor their comprehension by diagnosing the failure in comprehension and the illusion for comprehension (see Renkl et al., 1998) . In this light, this technique prompts learners to self-explain a given concept or procedure (Renkl et al., 1998), provided that the cognitive load is within the limit of WM capacity. Figure 3 maps these techniques for each category of cognitive load.

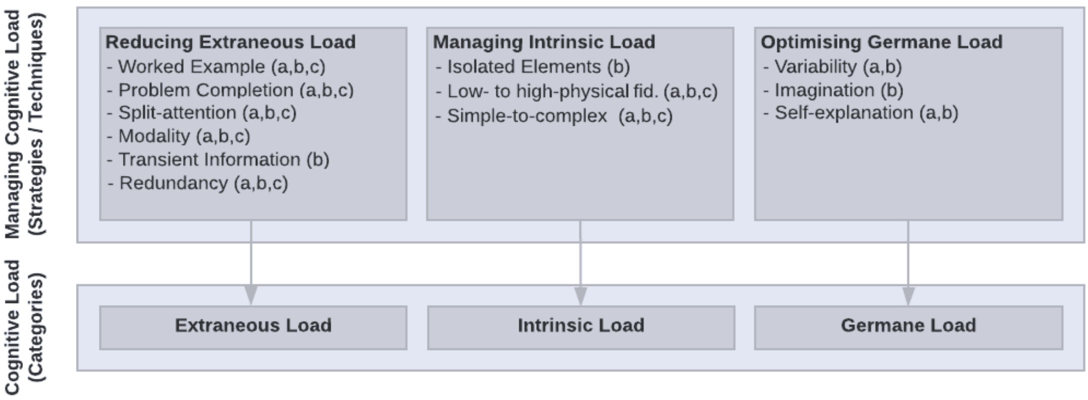


Figure 3. Mapping strategies and techniques to cognitive load categories

Figure 3 illustrates the strategies and techniques for managing cognitive load in EMR systems training. The upper box, shown in dashed lines, displays the strategies and techniques for managing cognitive load that is imposed by instructional materials. 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). 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 to the instructional materials that are used in training for EMR systems and to manage the cognitive load that they impose on trainees (e.g., medical and nursing staff in intensive care environments). Nevertheless, as discussed in Section 1.2, cognitive load in EMR systems training is an under-researched area, and the issue of training without causing cognitive overload is yet to be addressed (see Patel & Ozok, 2011). Consequently, these techniques have not been used to manage cognitive load in training on EMR systems. In this light, before applying these techniques, it is crucial to investigate (i) the actors' interpretation of cognitive load, and (ii) the way they regard these techniques for managing cognitive load in EMR systems training. Answers to these questions allow (i) in-depth understanding of cognitive load from the viewpoints of those involved (e.g., Designers, Trainers, and Trainees), and (ii) informed decision-making using suitable techniques (e.g., those regarded to have merit). Table 2, in the following pages, summarises these techniques in terms of description, intended learner, related techniques, instructional considerations, and references to seminal works.

Table 2. Strategies and techniques for managing cognitive load

| Strategy | Technique | Description | Intended Learners | Related Techniques | Instructional Considerations | Seminal Work |
|---|---|---|---|---|---|---|
| Reducing Extraneous Load | Worked Example *(Section 2.3.4.1)* | Provide learners with a *step-by-step* solution to a problem rather than asking them to search for the solution themselves. | Novice learners<br><br>*NB.* Expertise reversal effect applies to expert learners | - Problem Completion<br>- Split-attention<br>- Modality<br>- Redundancy<br>- Variability<br>- Imagination<br>- Self-explanation | To avoid passive learning, use in conjunction with alternation strategy (study an example, solve a problem) and completion strategy (partially completed solutions).<br>To achieve Worked Example effect, use with Split-attention, Modality, Redundancy, Variability, Imagination, and Self-explanation. | Sweller and Cooper (1985) |
| | Problem Completion *(Section 2.3.4.2)* | Provide learners with *partially completed* examples and ask them to complete the steps. | Novice learners<br><br>*NB.* Expertise reversal effect applies to expert learners | - Worked Example | Can be used when passive learning is concerned.<br>- For Worked Example: can be used as an alternative to those with many solution steps to offset their extraneous load. | van Merriënboer and Krammer (1987); van Merriënboer (1990) |
| | Split-attention *(Section 2.3.4.3)* | Replace multiple sources of information, which are distributed across space or time and unintelligible in isolation, with *single, integrated / synchronised* source. | Novice learners | - Worked Example<br>- Modality | Can be used when each source of information is essential to learning *and* unintelligible in isolation.<br>- For Worked Example: when designing worked examples, split-attention must be considered to achieve worked example effect.<br>- For modality: when presenting information multimodally, the source of information must remain integrated across space and time to avoid split-attention. | Tarmizi and Sweller (1988); Ward and Sweller (1990) |
| | Modality *(Section 2.3.4.4)* | Replace presentations of information that engage only visual or auditory channels (unimodal) with those engaging both *visual and auditory* channels (multimodal) of WM. | Novice learners | - Worked Example<br>- Split-attention<br>- Transient Information<br>- Redundancy | Can be used when multimodal presentation of information is superior to unimodal presentation.<br>- For Worked Example: when designing worked examples, modality must be considered | Mousavi et al. (1995) |

| Strategy | Technique | Description | Intended Learners | Related Techniques | Instructional Considerations | Seminal Work |
|---|---|---|---|---|---|---|
| | | | | | to achieve Worked Example effect.<br>- For Split-attention: each source of information must be essential to learning *and* unintelligible in isolation.<br>- For Trainset Information: the auditory component of multimodal presentation must be sufficiently short to avoid transiency.<br>- For Redundancy: the visual or auditory components of multimodal presentation of information must not *re-describe* one another to avoid redundancy. | |
| | Transient Information *(Section 2.3.4.5)* | Replace transient form of information (e.g., verbal, or auditory instructions) with *non-transient* forms (e.g., written instruction). | Novice learners | - Modality | Can be used when information is transient and cannot be readily held in learners' WM.<br>- For Modality: when presenting information multimodally, the auditory component must remain sufficiently short to avoid transiency. | Leahy and Sweller (2011) |
| | Redundancy *(Section 2.3.4.6)* | Replace multiple sources of information that are intelligible on their own (i.e. self-contained) with a *single self-explanatory* source. | Novice learners | - Worked Example<br>- Modality | Can be used when each source of information is self-contained *and* intelligible on its own.<br>- For Worked Example: when designing worked examples, modality must be considered to achieve worked example effect.<br>- For Modality: when presenting information multimodally, the sources of information must not *re-describe* one another to avoid redundancy. | Chandler and Sweller (1991) |

| Strategy | Technique | Description | Intended Learners | Related Techniques | Instructional Considerations | Seminal Work |
|---|---|---|---|---|---|---|
| Managing Intrinsic Load | Isolated Elements *(Section 2.3.5.1)* | Present complex information with multiple interacting elements sequentially from *isolated non-interacting elements* to all interacting elements. | Novice learners | N/A | Can be used to alter instructions with complex information involving multiple interacting elements. | Pollock et al. (2002) |
| | Low- to high-physical fidelity progression *(Section 2.3.5.2)* | Present complex learning tasks progressively from *low- to high-fidelity* environments. | Novice learners | N/A | Can be used to alter instructional environments for complex learning tasks. | Maran and Glavin (2003) |
| | Simple-to-complex progression *(Section 2.3.5.3)* | Present complex learning tasks progressively from a *simpler version* to a more complex version of the task. | Novice learners | N/A | Can be used to alter instructions for complex learning tasks. | van Merriënboer et al. (2003) |
| Optimising Germane Load | Variability *(Section 2.3.6.1)* | Provide learners with *a series of tasks that differ from one another* on all dimensions in which tasks differ in the real world, rather than a series of tasks with only similar surface features. | Expert learners*<br><br>*For novice learners, use with worked examples to first reduce extraneous load, then use variability, provided that their total cognitive load remains within WM limits. | - Worked Example | Can be used in situations where the total cognitive load is low. The resultant germane load should keep the total cognitive load within WM limits.<br>- For Worked Example: when multiple examples exist because *Variability* stimulates comparison. | Paas and van Merriënboer (1994) |
| | Imagination *(Section 2.3.6.2)* | Encourage learners to engage in imagining or mentally rehearsing a task, rather than only studying a task. | Expert learners*<br><br>*For novice learners, use when enough expertise developed and necessary schemas possessed to imagine a task adequately. | - Worked Example | Can be used for tasks that are fully or predominantly cognitive in nature. | Cooper et al. (2001) |
| | Self-explanation *(Section 2.3.6.3)* | Provide learners with a prompt to self-explain a given concept or procedure related to a task. | Expert learners*<br><br>*For novice learners, use when enough expertise developed and necessary schemas possessed to imagine a task adequately. | - Worked Example | Can be used for tasks when incorporating prior knowledge is beneficial for learning the tasks.<br>- For Worked Example: when single examples exist with prompts for *Self-explanation* to illicit sophisticated explanation. | Chi et al. (1989); Renkl et al. (1998) |

## 2.4. Chapter Summary

This chapter has addressed two topics. First, it discussed the association between cognitive load and EMR systems in the literature. In so doing, it examined the literature on this association and demonstrated that it had been discussed primarily in areas involving *design* and *use* of EMR systems as a prevalent form of HIT (Table 1). In this light, the chapter highlighted the under-researched area of *training* on these systems, in which cognitive load has an impairing effect. The chapter presented this area against a background where socio-technical variables, such as training and cognitive load, contributed to HIT problems involving human factors. This argument was then used to problematise the *cognitive load in EMR systems training*, as opposed to that in EMR systems design or use that prevails in the literature.

Second, it discussed the theoretical framework underpinning of this study. Specifically, the chapter presented Cognitive Load Theory as the theoretical lens to explain cognitive load and its impairing effect on learning with a focus on *instructional design* for EMR systems training. Using this theory, the chapter presented human cognitive architecture with its subsets of memory systems, including the *working memory* (Figure 1). The role and limitation of the working memory as a bottleneck to learning were also discussed. Similarly, the role of cognitive load and its associated categories—*intrinsic*, *extraneous*, and *germane* loads—was discussed, and their effects on the working memory were illustrated (Figure 2). The chapter then presented three instructional strategies to manage cognitive load. These strategies concentrated on each category of cognitive load and aimed at (i) decreasing extraneous load; (ii) managing intrinsic load; and (iii) optimising germane load. It continued by discussing multiple instructional techniques to achieve these strategies. These techniques, along with other subjects discussed above, were derived from a comprehensive review of the literature on cognitive load theory and research (Table 2). This review, in turn, resulted in an overview of the theory and its instructional benefits. This overview provides the basis on which to answer the research questions. It allows us to explain cognitive load in EMR systems training and discuss the merits of the instructional techniques proposed by this theory from the perspectives of actors with different roles in training on these systems.

# CHAPTER THREE

# RESEARCH METHODOLOGY

This chapter presents the methodology adopted for the study. It provides a brief overview of the methodology and presents its *design* and *conduct* for the study. In so doing, the chapter first presents the *design* of the study by describing (i) the research paradigm and the philosophical assumptions that informed the choice of paradigm; (ii) the research method and the justifications for the adopted method; and (iii) the research techniques for both data collection and data analysis. The chapter then describes the *conduct* of the study by detailing (i) the interviews and the associated processes; and (ii) the data analysis and the steps guiding its analytical process. The chapter concludes by summarising the key elements in the design and conduct of the study in a tabular format.

## 3.1. Overview

Methodology can be defined as the entire framework or design of the research, encompassing the choice of paradigm, methods, and techniques, to explore research questions and to make knowledge claims (Williamson & Johanson, 2018). It can also be viewed as the overall logic of an enquiry, including a set of philosophical assumptions or a paradigm as the foundation for the conduct of research as well as the choice of research methods and techniques (Cecez-Kecmanovic & Kennan, 2013). In other words, research methodology can be viewed as the overall logic that *aligns* the philosophical assumptions and the choice of research paradigm, methods, and techniques for the design and conduct of the study. These philosophical assumptions, as stressed by Cecez-Kecmanovic and Kennan (2013), are mainly related to ontology, epistemology, logic, and values (p. 132) which shape the researchers' view of the world (p. 149) and how they research the world (p. 127). In this light, the author first recognised his philosophical stance and then aligned the choices of research paradigm (*interpretivist*); research method (*case study research*); and research techniques for data collection (*semi-structured interviews*) and data analysis (*reflexive thematic analysis*) accordingly. These choices constitute the methodology adopted for this study.

## 3.2. Design of the Study

### 3.2.1. Research Paradigm

Research paradigm refers to "a set of underlying principles which provides a framework for understanding particular phenomena" (Williamson & Johanson, 2018, p. 582). As Kuhn (1970) argues, it is "a set of interrelated assumptions about the social world which provides a philosophical and conceptual framework for the systematic study of that world" (p.10). These assumptions are mainly concerned with perspectives on ontology, epistemology, logic, and values (Cecez-Kecmanovic & Kennan, 2013), which in turn, create a particular worldview for a researcher in which to understand a phenomenon. This particular worldview may be shared by a particular scientific community and act as what Ritzer (1975) refers to as the "the broadest unit of consensus within a science and serves to differentiate one scientific community (or sub-community) from another" (p. 7).

The author is cognizant of the fact that his assumptions about the nature and existence of reality (ontology); the nature of knowledge and ways of knowing (epistemology); the style of reasoning (the logic of explanation); and the place of values in research (research data as value-laden or value-free) may influence his view on and approach to a problem. Informed by these assumptions, the choice of paradigm for this study is the *interpretivist paradigm* which "emphasises natural settings together with individual and group perceptions of events and interactions within those settings" (Williamson & Johanson, 2018, p. 580). The reasons for this choice are twofold.

First, the choice of the interpretivist paradigm is *in line with* the author's perspective on ontology, epistemology, style of reasoning and place of values in research. From these perspectives, the author assumes that reality is socially constructed and is based on an individual's subjective interpretation (ontology). The author also assumes that knowledge about reality can be acquired through an individual's subjective experience of that reality (epistemology). The author also believes that inferences about general principles can be made from particular instances (inductive style of reasoning), and that values are embedded in humans and hence integrated with research (research data as value-laden).

Second, the choice of paradigm enables the author to approach the problem from a suitable perspective. As Mingers and Walsham (2010) argue, social sciences, as opposed to natural sciences, are dealing with phenomena that are fundamentally different. A research study that is informed by the interpretivist paradigm approaches these phenomena through their role and effect in social life (Klein & Myers, 1999) and from the perspectives of those involved (Nandhakumar & Jones, 1997). This, in turn, guides the methodological approach to the design and conduct of this study accordingly. This means adopting a critical and reflective approach in choosing the research methods and research techniques based on the research paradigm and the world view of the author. The author believes that the choice of the interpretivist paradigm allows the study to investigate the phenomenon from the perspectives of those involved (e.g., the actors with different roles in training on an EMR system) and to discuss their interpretations.

### 3.2.2. Research Method

Situating the study within a particular paradigm clarifies the range of research methods suited to that study (Cecez-Kecmanovic & Kennan, 2013). Following the choice of a research paradigm, this study adopts *a case study research* with an interpretive stance as its research method. Case study research, as defined by Yin (2003), is "an empirical enquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are clearly evident" (p. 13). It is appropriate for understanding the dynamics of a phenomenon within a single setting (Eisenhardt, 1989) where the action of individuals in the context is important (Yin, 2014) and the experience of the people involved is relevant (Darke et al., 1998). Case study research is particularly useful where the phenomenon under investigation is at its early stage of research (Benbasat et al., 1987) and the broadness and complexity of the phenomenon demand that the study be conducted within the context in which the phenomenon occurs (Cavaye, 1996). It has a distinct advantage when "a 'how' or 'why' question is being asked about a contemporary set of events over which a researcher has little or no control" (Yin, 2014, p. 14).

Case study research is a suitable method for this study for three reasons. First, the research problem has brought to the fore a phenomenon that is complex and contemporary (in this case, cognitive load contributing to HIT problems involving human factors) that requires thorough investigation within the natural setting in which it occurs (in this case, healthcare). The case study research enables investigating the phenomenon in a relevant context (in this case, NICU) with a focus on cognitive load in training on a widespread form of HIT in intensive care (in this case, an EMR system). Second, the case study research helps address another point that has been brought to the fore by the research problem, which involves human actions and experience. It enables the study to focus on the medical and nursing staff of NICU (i.e. intensivists) and the cognitive load that they experience while learning how to use their system. This way, the study can explore cognitive load as a probable element that may play a part in problems involving human factors resulting from their training/learning point of view. Third, the case study research method also enables this study to explore a phenomenon that is broad and complex but is not broadly addressed and studied. This way, the study can investigate the phenomenon, and, by posing the right research questions (e.g., *how* and *why* questions), explore the way or manner cognitive load may be a contributing element and explain the underlying reasons. These, in turn, enable the study to add to this body of knowledge incrementally.

Case study research has been used in various domains, such as information systems (Benbasat et al., 1987), healthcare (Pinnock et al., 2008) and medical learning (Pearson et al., 2010). One of the main reasons for this tradition lies in the *flexibility* inherent in this method. This is because case study research can lend itself to different paradigms such as positivist (Orlikowski & Baroudi, 1991), interpretivist (Klein & Myers, 1999) and critical paradigms (Myers & Klein, 2011). It can also lend itself either to deductive designs to test a theory (Sarker & Lee, 2002) or to inductive designs to build a theory (Eisenhardt, 1989) and use theory as an explanatory lens (Jones & Karsten, 2008). Case study research can also be flexible in using different types of data such as quantitative or qualitative data through different data collection techniques (e.g., questionnaires or interviews) and data analysis techniques (e.g., statistical analysis or thematic analysis).

This flexibility enables this study to situate the method in the interpretivist paradigm, to take an inductive style of reasoning, and to adopt a qualitative approach to data collection and data analysis. An interpretive case study, for instance, allows the study to investigate the cognitive load within its natural settings and to acquire knowledge from those who experience cognitive load while learning how to perform a task with an EMR system. This way, the meaning attributed to this experience can be explained through their own language, perceptions, experiences, and perspectives.

Similarly, this flexibility allows the study to take an inductive stance and use CLT as its theoretical lens. In doing so, the study can use the theoretical framework of this theory to provide a detailed description of (i) what is cognitive load; (ii) what are the categories of cognitive load; (iii) how to study the effects of cognitive load; and (iv) how to use specific strategies and techniques to manage cognitive load. This way, the study can utilise the strategies offered by this theory for managing cognitive load and the techniques that are specifically designed to fulfil those strategies when designing instructional materials for training on EMR systems.

In a similar manner, this flexibility also enables the study to use qualitative data such as words, views, and interpretations of different actors in an EMR system training in their own language based on their own experience. In doing so, the study can use semi-structured interviews to gather sufficient data from individuals who are directly involved. The study can also use reflexive thematic analysis to identify common ideas or themes that emerge based on the phenomenon under investigation. In designing this case study research with rigour, the author paid specific attention to the following:

*i)* the unit of analysis (cognitive load at the individual level)

*ii)* the number of cases (a single case study, as unique and revelatory for in-depth analysis)

*iii)* the use of theory (CLT as the theoretical lens to understand the cognitive load and to provide a rich explanation of how it may influence working memory and learning) and

*iv)* the collection and analysis of data (multiple techniques and sources to strengthen the credibility and to enable different perspectives and interpretations).

### 3.2.3. Research Techniques

As discussed earlier, situating the research within a particular paradigm, defines the range of methods available to conduct the study, and subsequently, the number of techniques to collect and analyse data for that study. Given the chosen paradigm (interpretivist paradigm), and the adopted method (case study research); this study uses the following techniques for data collection (semi-structured interview) and data analysis (reflexive thematic analysis). Research technique here is viewed as "a procedure or tool for undertaking research processes, e.g., selecting samples, collection and analysing data" (Williamson & Johanson, 2018, p. 584).

#### *3.2.3.1. Data Collection Technique*

This study will use individual interviews as the primary technique for data collection. Interviews are purposeful discussions between people (Kahn & Cannell, 1957), and when used to their full potential, are a powerful technique for qualitative data collection (Myers & Newman, 2007). Interviews can take various forms (Fontana & Frey, 2000), and can be used in various paradigms (Myers & Newman, 2007).

In the interpretivist tradition, interviews are generally used to elicit meaning from people and to understand those meanings from their points of view (Williamson, 2018). They are likely to take less-structured forms (e.g., unstructured or semi-structured), which offer more flexibility to capture the participant's perspective (Williamson, 2018). Semi-structured forms, in particular, offer the interviewer the flexibility to ask open-ended questions or alter the sequence of questions while remaining focused on the critical purpose of questioning. This way, the interviewer can create an environment to encourage the respondent and to evoke in-depth and focused responses.

This study, therefore, uses *semi-structured interviews* with open-ended questions as its data collection technique. The reason for this choice lies in the paradigm and the method adopted for this study. With respect to the chosen paradigm, this form of interview enables the study to focus on the respondent's perceptions of cognitive load in training on their EMR system. With respect to the adopted method, it enables the study to focus on (i) the phenomenon in context and (ii) individuals' actions and experiences. The conduct of the interviews is detailed in Section 3.3.1.

#### *3.2.3.2. Data Analysis Technique*

The interview data, in the shape of recordings and transcripts, are analysed for sense-making. The study uses *thematic analysis* as a qualitative data analysis approach to convert the raw interview data into sensible results for reporting and dissemination at the later stage. Thematic analysis, as emphasised by Williamson et al. (2018), can be viewed as an inductive approach through which the researcher identifies thematic patterns in the unstructured content of the data.

There are numerous approaches to thematic analysis, which differ in terms of their underlying philosophy, procedures, and even conceptualisation of key concepts such as coding and themes. Braun et al. (2018) stress that the shared name of thematic analysis can obscure this "divergence" (p. 3) and suggest that thematic analysis could be better understood as an "umbrella term" (p. 1). This divergence often confuses researchers when choosing a suitable framework for their study or impairs the quality of their work with inconsistencies in their choice of key concepts or procedures.

To avoid this, Braun et al. (2018) proposed a typology of different approaches to thematic analysis, which can guide the choice of a suitable framework for the analytic process of a study. The typology comprises three approaches to thematic analysis, namely the *Coding Reliability*, *Reflexive* and *Codebook* approaches (p. 5). This study adopts the reflexive approach to thematic analysis guided by the framework suggested by Braun and Clarke (2006). The conduct of data analysis using this framework is detailed in Section 3.3.2.

## 3.3. Conduct of the Study

### 3.3.1. Collection of Data

The process of data collection took place between March and July 2019. It involved obtaining ethics approval, selecting the site, identifying the sample, and conducting the interviews. These are detailed below.

#### *3.3.1.1. The Ethics Approval*

Before conducting data collection, an ethics application was submitted to the Participating Organisation's Human Research Ethics Committee. Approval was obtained in late November 2018 (Appendix A). The research project was registered with Monash University's Human Research Ethics Committee (MUHREC) in February 2019 (Appendix B). Both Ethics Committees approved all the required documents. These documents comprise the Explanatory Statement; Consent Form; Study Pamphlet; and Interview Protocol (Appendices C – F).

#### *3.3.1.2. The Site*

The targeted site for this study was a Neonatal Intensive Care Unit at a large public hospital in Melbourne, Australia. The reasons for choosing this site were threefold. First, they had adopted more than one EMR system over time. Second, they had designed and delivered instructions for their training. Third, they aspired to enhance their EMR system training and were willing to participate in the study.

#### *3.3.1.3. The Sample*

The study adopted the *non-probability sampling* technique. In so doing, it used *purposive* and *snowball* sampling to recruit participants. As stressed by Williamson (2018), interpretivists aspire to use non-probability sampling and require small samples. Nevertheless, the optimal sample size for non-probability sampling is generally determined by *saturation*. That is, the point where the researcher should stop adding cases (Eisenhardt, 1989) because s/he cannot hear or see new information (Savin-Baden & Major, 2013). The sample comprised *nine* participants. All participants had an active role in training on their first EMR system as the second system was at the early stage of adoption. The participants comprised two Designers, two Trainers, and five Trainees. Of those, four participants were medial staff, while five were nursing staff. All participants were anonymised and assigned an alpha-numeric code (P01 to P09). Table 3, on the following page, profiles the participants recruited.

Table 3. The profile of the participants

| **Role in Training** | **Participant Code** | **Role in NICU** | **Sampling Strategy** | **Years of Experience** | | | |
|---|---|---|---|---|---|---|---|
| | | | | **Professional** | **Role in NICU** | **Current EMR system** | **Other EMR systems** |
| Designer | P01 | Consultant – Senior medical Neonatologist *(Medical Staff)* | Purposive | 25 and above | 10 - 15 | 5 - 10 | 10 - 15 |
| | P07 | Nurse Unit Manager *(Nursing Staff)* | Snowball | 25 and above | 10 - 15 | 5 - 10 | 0 - 5 |
| Trainer | P02 | Clinical Nurse Specialist *(Nursing Staff)* | Snowball | 25 and above | 5 - 10 | 5 - 10 | 5 - 10 |
| | P04 | Director of Clinical Operations *(Nursing Staff)* | Purposive | 20 - 25 | 0 - 5 | 5 - 10 | 0 - 5 |
| Trainee | P03 | Fellow *(Medical Staff)* | Snowball | 5 - 10 | 5 - 10 | 0 - 5 | 0 - 5 |
| | P05 | Clinical Nurse Specialist *(Nursing Staff)* | Snowball | 15 - 20 | 10 - 15 | 5 - 10 | 0 - 5 |
| | P06 | Nurse Unit Manager *(Nursing Staff)* | Snowball | 5 - 10 | 5 - 10 | 5 - 10 | 0 - 5 |
| | P08 | Fellow *(Medical Staff)* | Snowball | 5 - 10 | 0 - 5 | 0 - 5 | 5 - 10 |
| | P09 | Fellow *(Medical Staff)* | Snowball | 5 - 10 | 0 - 5 | 0 - 5 | 5 - 10 |

#### *3.3.1.4. The Interviews*

Overall, nine interviews totalling 4.5 hours were conducted. The interviews focused on the adopted EMR system (the first system). With the participants' consent, each interview was audio-recorded by two different devices to avoid potential loss of data. The recordings were transcribed verbatim to the appropriate level of detail, checked for accuracy, and fully anonymised. The transcripts covered over 35000 words in 77 pages of A4 size. The instrument used for the interviews was an approved interview protocol. It comprised (i) definition of terms; (ii) demographic questions; and (iii) interview questions in different sets for each actor. The interview questions were derived from CLT literature and organised in *three sections* covering *eighteen questions*. Each interview question was specifically worded for each actor and was designed to solicit the their views on (i) awareness and experience of cognitive load; (ii) instructional techniques targeting each category of cognitive load; and (iii) questions about the efficacy of instructional materials and suggestions for improvements (see Appendix F).[1] The questions were piloted and subsequently recalibrated. A designer and a trainer participated in the piloting the questions. Both individuals were members of NICU medical and nursing staff at the Participating Organisation. They also designed and delivered instructional materials for their EMR system training.

### 3.3.2. Analysis of Data

Data analysis took place from July to November 2019. The process involved identifying a research technique for data analysis (Thematic Analysis) and adopting a framework to guide the analysis (Braun & Clarke, 2006). The description of the adopted technique and the justification of the chosen framework are detailed below.

#### *3.3.2.1. The Technique*

Thematic Analysis (TA) can be defined as a technique for "identifying, analysing, and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79). TA was initially thought to have originated in the early 1970s (see Joffe, 2011). However, it was later revealed that the term had been in use as early as the 1930s (see Kinsky & Strunk, 1933, and Lazarsfeld & Merton, 1944, both cited in Braun et al., 2018). According to Braun et al. (2018), the use of thematic analysis for analysing qualitative data had taken momentum between the 1980s and 1990s when interest in qualitative research exploded (e.g., Dapkus, 1985, and Aronson, 1994, both cited in Braun et al., 2018). Although TA had been a poorly demarcated yet widely used approach in qualitative research for some time (Braun & Clarke, 2006), it is now recognised as an approach to analysis in its own right (Braun et al., 2018).

[1] The last table in Appendix F details the interview questions and maps each question to each actor.

There are numerous approaches to TA. These approaches, however, differ in their underlying philosophy, procedures, and conceptualisation of key concepts such as coding and themes. Braun et al. (2018) stressed that the shared name of *thematic analysis* could obscure this "divergence" (p. 3) and suggested that it could be better understood as an "umbrella term" (p. 1). Therefore, they proposed a typology of different approaches to TA, which can guide the choice of a suitable framework for the analytical process of a study. This typology includes three approaches to TA, namely the *Coding Reliability*; *Reflexive*; and *Codebook* approaches (p. 5).

*Coding Reliability*, represented by the likes of Boyatzis (1998) and Joffe and Yardley (2004), approaches TA with an emphasis on the reliability of coding. This approach stresses a structured codebook and multiple coders who should reach an acceptable level of consensus (e.g., a Kappa higher than 0.80). It is informed by a positivist philosophy and has strong echoes of "the scientific method" (Braun et al., 2018, p. 5) where hypotheses (themes) are developed, tested (evidenced in the codebook), and the researcher's bias is controlled (through consensus) for reliable and replicable observations. In Coding Reliability, themes are conceptualised as what Braun et al. (2018) refer to as "domain summary" (p. 4). That is, summarising what participants said about a topic such as an interview question. Domain summaries are often derived from data collection questions and drive the coding process. In this approach, the coding process is guided by a coding frame or a codebook to allow researchers to "categorise" the data into "predetermined" themes in an accurate manner (p. 4).

The *Reflexive* approach, embodied by the work of Braun and Clarke (2006), is underpinned by a qualitative philosophy. It stresses meaning as contextual, reality as multiple, and researcher subjectivity as a resource (Braun et al., 2018). In this approach, themes are conceptualised as patterned meanings, which can be explicitly or implicitly evident in the data. Themes are viewed as an analytic output of the coding process and can take the shape of domain summaries (p. 6) or patterns of shared meaning that are organised around a central organising idea (p. 3). The coding in the reflexive approach is an iterative and evolving process (p. 6).

The *Codebook* approach is situated between these two approaches. It is broadly informed by a qualitative philosophy similar to the Reflexive approach but also shares some aspects with the Codebook Reliability approach. Chief amongst these is the process of coding that uses a structured coding framework, which often does not require consensus between the researchers. Themes are generally conceptualised as domain summaries and are often determined in advance. The analyses in this approach are exemplified by template analysis (King & Brooks, 2017), framework analysis (Ritchie & Spencer, 2002), and matrix analysis (Miles & Huberman, 1994).

This study adopted the framework suggested by Braun and Clarke (2006) for two reasons. First, the suggested framework, which embodies the reflexive approach to thematic analysis, is underpinned by a qualitative philosophy. This philosophy, as stated earlier, views reality as multiple, meaning as contextual, and researcher subjectivity as a resource (Braun et al., 2018, p. 6). This philosophy is *fully aligned* with the philosophical assumptions that underly the adopted methodology for this study. These include assumptions about ontology (reality as socially constructed) and epistemology (knowledge as subjectively acquired). They also include assumptions about the style of reasoning (inference as inductively drawn) and the place of values in research (research as value-laden). Together, these assumptions informed the study's design.

Second, the suggested framework helps determine the analysis form and outcome and guide its process. The framework requires the author to decide on key elements the conceptualisation of themes (underlying pattern of shared meaning vs summary of an aspect); type of intended analysis (rich description of data set vs detailed account of an aspect); identification of themes (inductive vs deductive); and the level at which themes are identified (semantic vs latent). Each decision has implications for the form and the outcome of the analysis which are elaborated in the following pages (see Section 3.3.2.2.). Also, the framework requires the author to apply a procedure to guide the analytical process. It provides a 6-step instruction to direct each process of the analysis (Braun & Clarke, 2006, p. 87) and offers a 15-point criterion to ensure rigour (Braun & Clarke, 2006, p. 96). These are also detailed in the following pages (see Section 3.3.2.3).

#### *3.3.2.2. The Decisions*

As stressed by Braun and Clarke (2006, pp. 81-82), thematic analysis involves certain *decisions* that need to be addressed explicitly *before* the analysis. These decisions can help shape the form of the analysis and determine its outcomes. These decisions involved the following:

*Decision 1: Conceptualising a theme*

The first decision involved conceptualising a theme. "A theme captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the data set" (Braun & Clarke, 2006, p. 82). This definition highlights two key elements. First, the extent to which a patterned meaning occurs in the data set. Second, the degree to which it captures something important to answer the research question.

The first element focuses on the prevalence of patterned meanings in terms of space within a data item or instances across a data set. It tends to stress the quantifiable aspect of patterned meanings such as the number of times they appear. However, as discussed by Braun and Clarke (2006), the number of instances is not inherently a guarantor of the cruciality of a theme. The second element, on the other hand, concentrates on what Braun and Clarke (2006) refer to as the "keyness" of a theme (p. 82). It places more stress on the qualitative aspect of a theme in terms of how significantly it helps answer the research question. This aspect is not necessarily the function of quantifiable measures.

In determining what counts as a theme, this study maintained a balance between the two elements. In so doing, it relied on the author's judgement on patterned meanings that may not necessarily be the most prevalent, but which captured something crucial about the research questions. During the analysis, the author remained consistent in conceptualising the themes, transparent in identifying them, and truthful in reporting their existence.

*Decision 2: Type of analysis*

The second decision revolved around the type of analysis intended for the study. It involved deciding whether the analysis would be in the form of a rich description of the data set or a detailed account of a particular aspect of data. That is, to determine whether the analysis would provide a detailed thematic description to accurately reflect the content of the data set in its entirety or offer a detailed description of a specific aspect of it (e.g., a specific theme). This study provided a rich description of its entire dataset. The author was cognizant of the fact that the study would culminate in a relatively short thesis, which may result in some loss of depth or richness of description. Nevertheless, as discussed earlier (see pages 3 and 26), cognitive load in EMR systems training is an under-researched area, and the decision to provide an in-depth description of the data set could help shed light on this area of research by giving a sense of the predominant themes.

*Decision 3: Identifying a theme*

The third decision involved adopting an approach to identify a theme. This meant deciding on either a *deductive* approach, where a theme is derived from the theoretical ideas that the researcher brings to the research (Joffe, 2011), or an *inductive* approach, where a theme is drawn from the data itself (Braun & Clarke, 2006). In other words, in a deductive approach, what drives the analysis is the researcher's theoretical position or interest, whereas, in an inductive approach, it is the data that drives the analysis.

According to Braun and Clarke (2006, p. 84), the deductive approach tends to provide more of a detailed account of some aspects of data and less of a rich description of the entire dataset. Considering the type of analysis chosen for this study (i.e. rich description of data set), this study identified themes *inductively*. This way, the author was able to ground the theme in the data and remain open to the new themes that emerged.

*Decision 4: Level of theme identification*

The fourth decision involved the level at which a theme was identified. These levels comprised a *semantic* level where a theme is identified at the surface meaning of data, and a *latent* level where a theme can be identified through the underlying concept or ideas that inform those meanings. At the semantic level, the focus is on the explicit meaning of data that is directly observable, whereas, at the latent level, it goes beyond and concentrates on the tacit underpinnings of meanings. The latter is discernible through an interpretive or interrogative view of the data.

This study identified themes at the *latent* level. This decision, however, should not be interpreted as meaning that the patterned meanings at the semantic level were overlooked. On the contrary, the author explored the explicit meaning of data but leaned towards the implicit ideas (behind the surface) that informed them. This way, the author progressed from description to interpretation of the patterned meanings in the data and discussed their significance and implications in a broader sense.

*Decision 5: Epistemology*

The fifth decision concerned epistemology, the nature of knowledge and ways of knowing. The author addressed his epistemological position as an integral part of the adopted methodology. Nevertheless, it is necessary to reiterate this position at this stage as it guides how one describes data and informs how one theorises meaning (Braun & Clarke, 2006, p. 85).

This study assumed that knowledge about reality could be acquired through the subjective experience of that reality. In this sense, the study focused on the context that enabled participants' experiences and their interpretation of those experiences. The details about the philosophical assumptions, including those on epistemology, which informed the choice of research paradigm, method, and techniques were discussed in detail in the previous section.

*Decision 6: Questions*

The last decision revolved around *questions* in qualitative research and their relationships. According to Braun and Clarke (2006), these comprise questions that (i) drive the study (research questions); (ii) collect data for the study (interview questions); and (iii) guide the coding and analysis of those data. They suggest a *disjuncture* between these questions and stress that they should be considered before and during thematic analysis (pp. 85-86). This study complied and used the questions as they were intended. Table 4 summarises these questions and the decisions discussed above. These decisions were made prior to the analysis of the collected data.

Table 4. The decisions shaping the analysis

| **Decisions** | **Descriptions** |
|---|---|
| 1. Conceptualising a theme | A consistent balance between prevalence and keyness |
| 2. Type of analysis | A rich description of the entire data set (to give a sense of predominant themes) |
| 3. Identifying a theme | An inductive approach (to derive data-driven themes) |
| 4. Level of theme identification | At latent level (to interpret the meanings and discuss their implications) |
| 5. Epistemology | Knowledge as a subjective experience of a socially constructed reality (interpretivist) |
| 6. Key questions | - Research question (to guide the study but subject to refinement)<br>- Data collection questions (to collect data only / not used as themes)<br>- Question guiding coding and analysis (to address a themes' meaning, underpinning assumptions, important implications, causing conditions, and revealing stories) |

### *3.3.2.3. The Steps*

The adopted framework offers a 6-step guideline for conducting the analytic process. It is important to note that these steps are not a "linear" (Braun & Clarke, 2006, p. 86) but a "reflective and recursive" process (Braun et al., 2018, p. 10). What follows describes each step and how they were applied to this study.

*Step 1: Familiarisation with data*

This step was about *immersion* in the data to know its depth and breadth. It was a crucial entry point to the data, which allowed for reflexibility—e.g., the researchers asking questions of themselves and how they respond to the data (Braun et al., 2018, p. 10). This step involved (i) transcribing the data; (ii) repeated reading of the data; and (iii) making notes on initial ideas (Braun & Clarke, 2006, p. 87).

For this study, the interview recordings were transcribed using NVivo Transcription—a service offered by the developer of NVivo, QSR International. The author checked each interview transcript with its audio recording for accuracy to ensure that it remained *true* to its original nature (e.g., with a focus on punctuation placement to retain the exact meaning). The author also made sure that the transcripts are *orthographic* to provide an appropriate level of detail with a verbatim account of the verbal and nonverbal utterances (e.g., pauses, inbreathes, coughs, and laughter). The interview transcripts were reviewed *twice*, and notes were taken based on the research questions and the broader questions about what is going on in the data. The interview transcripts were then imported into the NVivo environment (see Appendix G).

*Step 2: Generating initial codes*

This step involved a more in-depth engagement with the data to generate codes. Codes, as defined by Braun and Clarke (2006), refer to the most basic elements of data that can be assessed in a meaningful way regarding the phenomenon. Generating codes involved (i) identifying those elements succinctly and systematically; and (ii) collating the data relevant to each code (p. 87).

For this study, codes were generated *inductively* and progressed from the *semantic* to *latent* levels of meanings. Although it is stressed by Braun et al. (2018) that initial coding for TA projects is often semantic due to the difficulty in seeing the meanings beyond the obvious (p. 11), the author progressively identified the meanings at the latent level to understand the underlying meanings of what was said by participants. In the next page, Table 5 illustrates an earlier example of coding of an extract from a data item.

Table 5. An illustrative data extract with an earlier example of coding

| Data Extract | Coded for |
|---|---|
| *SH: Do you know what cognitive load is?* | - |
| P01: (um) I have an idea, yes. | 1. Awareness of CL. |
| *SH: Can you describe it in your own words, please?* | - |
| P01: Yeah, I think basically (um), there is the decision about people try to do problem solving of one specific task (um) and then also trying to have a lot of information in order to come up with the best solution to a to a problem. The cognitive load, I think, could be due to the one task itself (um, pause), I mean excessive cognitive load, I guess. If the task is very complicated, it requires (um) pulling information from many sources into one in order to the solve a problem. So, that is the tasks could be very complicated and one of the examples in the NICU, might be trying to get information in order to manage ventilation, for example. And this could be trying to assess and get information about the baby, and then from the nurses (um), our own examination from the baby. And also, information from (cough) X-ray, information from blood test, et cetera in order to formulate, you know, a plan to manage the babies and ventilation. So, another example might be there could be more than one task that the person is involved in, and then there are other urgent task that comes out (um) that is not really within the person's control but something urgent that comes up, (um) and then (cough) there is also, I think, interruptions maybe from other staff because we also have, for example, the urgent question about whether (um), you know, about a medication order that the Doctors write, and it is not quite clear to the nurses, they have to clarify it (um) before they give the medication, and then if the doctor is also involved in another task, a complicated task before, I guess is overall cognitive load is for the doctor. | 2. Association of CL with tasks and problem-solving using a lot of information.<br><br>3. Association of CL with pulling information from many sources.<br><br>4. Example of CL in NICU (information to manage ventilation).<br><br>5. Association of CL with tasks other than the one at hand (urgent tasks).<br><br>6. Association of CL with interruptions from other staff (urgent questions).<br><br>7. Example of CL in NICU (unclear information written by other doctors or nurses). |
| *SH: So basically, my understanding from your words is that (pause) you associate cognitive load with the task or tasks, and the information that is required to perform that task. And, you also see some sources of (um) sources that cause cognitive load including interruptions and things like that, right?* | - |
| P01: Yes, yes (emphasis). | - |

SH: The author's initials; P01: Participant No. 1; CL: Cognitive Load

*Step 3: Searching for themes*

This step continued the active processes of the previous steps. In this step, the analytic focus shifted from generating codes to constructing themes. This step involved (i) sorting codes into potential themes; and (ii) collating all the coded data relevant to each potential theme. This way, the codes could be analysed and combined to form an *overarching* theme (Braun & Clarke, 2006, p. 89).

In this study, this step began after all data were coded and collated. Some codes appeared more relevant to one another and displayed certain patterns in the data set. These patterns represented the prevalence of the relevant codes. For example, in a broader sense, a sizable portion of codes pointed to *justifications* for choosing a specific instructional technique. The data extract for these codes showed certain *indications of reasons* for choosing that technique. A closer look at the codes and their data extracts revealed that these indications recurred across *most* techniques. Concurrently, it also revealed that justifying *why* a technique was chosen had some significance to the research questions. In particular, for the second research question, which explored how these techniques were regarded, justifications for choosing a specific technique could capture some degree of importance. In other words, it could explain, to some extent, why a technique was regarded in a certain way. Consequently, this pattern in the data, which pointed to justifications for choosing techniques, was considered as a *candidate theme*. The same process was repeated to identify other candidate themes. In this process, all codes were reanalysed, and some data extracts were recorded. As a result, some codes displayed a closer relationship, while others showed no particular relationship to others.

*Step 4: Reviewing themes*

This step revolved around refining the *candidate themes* developed earlier. It involved (i) reviewing themes to ensure coherence; and (ii) generating a thematic map to reflect their meanings accurately. In this step, the candidate themes were reviewed *at the level of data extracts* (level 1). The collated extracts for each theme were checked to ensure that they formed a coherent pattern. Once the theme captured the *contours of the coded data* (Braun & Clarke, 2006, p. 91), a thematic map for the themes was developed. The themes were then reviewed *at the level of data set* (level 2). The entire data set was reviewed once more to ensure the validity of the themes, and to code additional data where necessary. Once completed, the thematic map was revised and finalised. In the end, this step resulted in (i) a clear idea of themes and what they reflected about the data (Braun & Clarke, 2006, p. 92); and (ii) a satisfactory thematic map that accurately reflected the meanings evident in the data set (Braun & Clarke, 2006, p. 91). Figure 4, in the following page, presents a thematic map at an earlier stage of analysis.

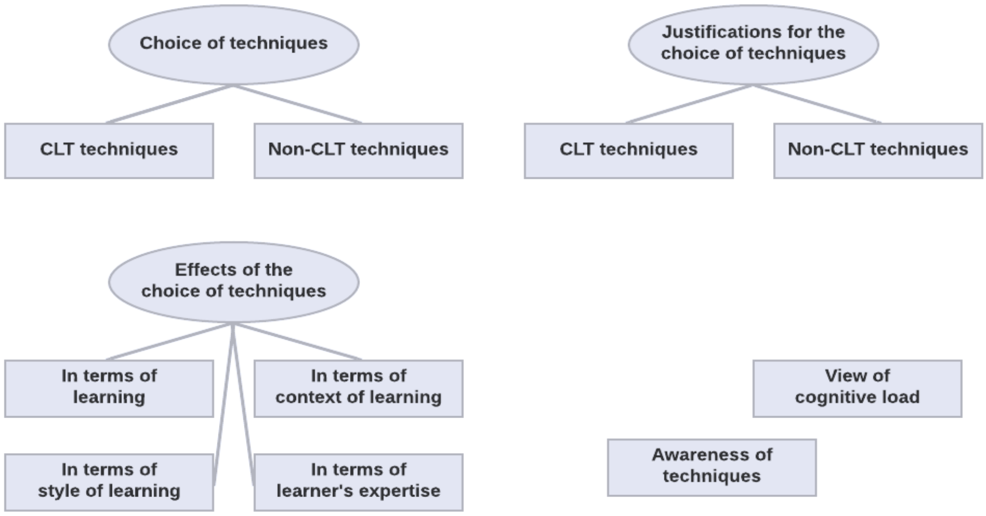


Figure 4. A thematic map at an earlier stage of analysis

As illustrated, three patterns recurred across the data set. These patterns pointed to the *choices*; *justifications*; and *effects* of the techniques. Also, there were other patterns in the data but not recurring across the data set to the same extent as the other three patterns. Figure 5 presents the revised thematic map at a later stage of the analysis after reviewing themes.

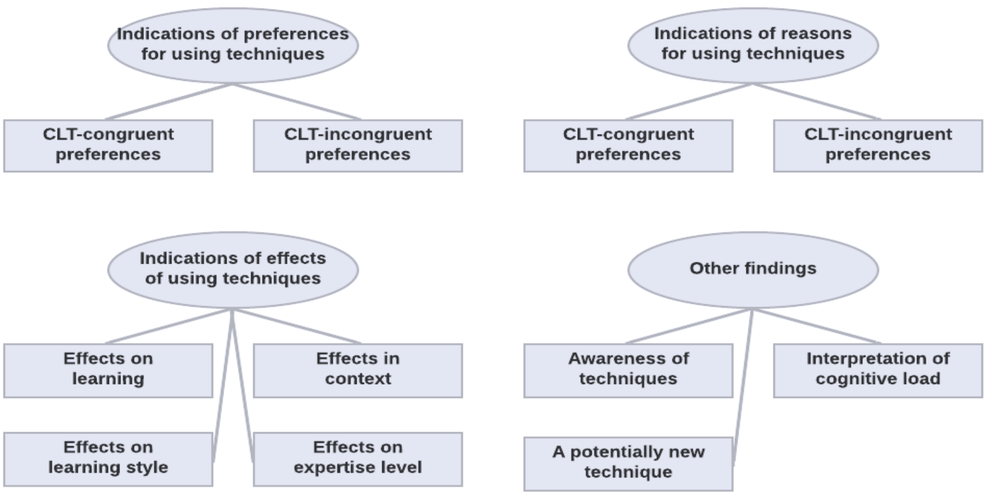


Figure 5. A revised thematic map at a later stage of analysis

As illustrated, the first three patterns were refined. These patterns reflected the *indications of preferences*; *reasons*; and *effects* of using the data. The other patterns were later reorganised under *other findings* from the analytic process.

*Step 5: Defining and naming themes*

This step concerned finalising the themes. It involved (i) refining the specifics of each theme; and (ii) generating clear names and definitions for them. After developing the thematic map, the author further *defined* and *refined* each theme. The idea here was to identify the *essence* of what each theme was about, and the aspects of data they captured (Braun & Clarke, 2006, p. 92). The author also determined if the themes required sub-themes. Here, the idea was to give a structure to a complex theme and to show the hierarchy of meaning within the data. As this process progressed, three points became apparent. First, repeating the process did not result in additional codes or themes. Second, the refined thematic map did not show a better structural fit with the data set. Third, the data collected from the last interviews did not change this structural fit. The identified themes began to make sense and narrate a cohesive story about the data set. The author aimed to name each theme in such a way that it would provide readers with a clear understanding of what the theme was about. These themes and their subthemes are presented in the next chapter (see Section 4.2).

*Step 6: Producing a report*

This step involved producing the analysis report. After finalising the themes, the author produced a report with a coherent and logical account of the data. The report aimed to provide sufficient evidence of themes within the data to convince the readers of the validity and merit of the analysis. That report has culminated in this thesis. Table 6 provides a summary of the steps and the activities involved.

Table 6. The steps in the analytical process

| **Analytic Processes** | **Key Activities** |
|---|---|
| 1. Familiarisation with data | 1.1. Transcribing the data |
| | 1.2. Repeated reading of the data |
| | 1.3. Taking notes on initial ideas |
| 2. Generating initial codes | 2.1. Identifying codes systematically |
| | 2.2. Collating all the coded data relevant to each potential theme |
| 3. Searching for themes | 3.1. Sorting codes into potential themes |
| | 3.2. Collating all data relevant to potential themes |
| 4. Reviewing the themes | 4.1. Reviewing potential themes |
| | 4.2. Generating a thematic map |
| 5. Defining and naming themes | 5.1. Defining the specifics of each theme |
| | 5.2. Generating name for each theme |
| 6. Producing a report | 6.1. Producing a scholarly report |

#### *3.3.2.4. Demonstrated Rigour*

As stated earlier, the adopted framework also provides a 15-point checklist of criteria for a rigorous thematic analysis (Braun & Clarke, 2006, p. 96). Table 7 presents these criteria and demonstrates the way the analytical process met these criteria.

Table 7. The criteria for rigour in thematic analysis (Adopted from Braun & Clark, 2006, p. 96)

| **Process** | **Criteria** | **Demonstration** |
|---|---|---|
| 1. Transcription | 1.1. The data have been transcribed to an appropriate level of detail, and the transcripts have been checked against the tapes for 'accuracy'. | Checked against audio recording twice. Transcripts are orthographic with a verbatim account of utterances. *(see Step 1 in Section 3.3.2.3)* |
| 2. Coding | 2.1. Each data item has been given equal attention in the coding process. | Codes were initially identified and then rechecked against their data extracts in NVivo environment. Each code was assigned a unique Data ID representing matching data extracts *(see Appendix H).* |
| | 2.2. Themes have not been generated from a few vivid examples (an anecdotal approach), but instead the coding process has been thorough, inclusive and comprehensive. | Themes were conceptualised with a balance between *prevalence across data set* and *keyness to research questions*. They were also identified *inductively* hence grounded in the data. Also, they were identified at the *latent* level to capture underlying meanings *(see Decisions 1, 3, and 4 in Section 3.3.2.2).* |
| | 2.3. All relevant extracts for all each theme have been collated. | All data extracts relevant to each theme were collated in one location within NVivo environment *(see Appendix G).* |
| | 2.4. Themes have been checked against each other and back to the original data set. | The themes were reviewed at two levels against (i) the coded data extracts (level 1); and (ii) the entire data set (level 2). This ensured that the themes formed a coherent pattern and upheld validity in relation to the data set *(see Step 4 in Section 3.3.2.3).* |
| | 2.5. Themes are internally coherent, consistent, and distinctive. | Same as above |
| 3. Analysis | 3.1. Data have been analysed – interpreted, made sense of – rather than just paraphrased or described. | Themes were identified *inductively* at the *latent* level to capture their underlying meanings. This ensured *interpretation* rather than a description of their meanings *(see Decisions 3 and 4 in Section 3.3.2.2).* |
| | 3.2. Analysis and data match each other – the extracts illustrate the analytic claims. | The analytic claims are grounded in the data. These claims are reported in Chapter Four through illustrative data extracts *(see Sections 4.2.1 to 4.2.4).* |
| | 3.3. Analysis tells a convincing and well-organized story about the data and topic. | The process of analysis was detailed in terms of *decisions* (to be addressed before) and *steps* (to follow during) the process *(See the details in Sections 3.3.2.2 and 3.3.2.3).* |
| | 3.4. A good balance between analytic narrative and illustrative extracts is provided. | The analytic narrative is based on the data extracts. This narrative is presented in Chapter Four *(see Sections 4.2.1 to 4.2.4).* |
| 4. Overall | 4.1. Enough time has been allocated to complete all phases of the analysis adequately, without rushing a phase or giving it a once-over-lightly. | The process of data analysis took around five months to complete. During this period, the author had ample time to focus on all steps. The *preliminary findings* from the analysis were submitted to ACIS 2019 in August *(see Publications Arising during the Research).* |
| 5. Written Report | 5.1. The assumptions about, and specific approach to, thematic analysis are clearly explicated. | The approach to thematic analysis (Reflexive) and the framework to guide the analysis process (Braun & Clarke, 2006) was discussed in this chapter. Similarly, the methodological underpinnings of the study and their alignment with those of the adopted method were also discussed *(see Section 3.3.2.1).* |
| | 5.2. There is a good fit between what you claim you do, and what you show you have done; i.e., described method and reported analysis are consistent. | Each step in the analytical process described the activities involved in line with the framework suggested by Braun and Clarke (2006). Each step was then detailed for the study and how it was applied to its analysis process *(see Steps 1 to 6 in Section 3.3.2.3).* |
| | 5.3. The language and concepts used in the report are consistent with the epistemological position of the analysis. | The author detailed his epistemological position and how it, along with other philosophical positions, shaped the design of the study. The reporting of the study was in full alignment with these positions *(see Section 3.2).* |
| | 5.4. The researcher is positioned as active in the research process; themes do not just 'emerge'. | Given the philosophical underpinning of reflexive thematic analysis, particularly its view on the researcher's subjectivity, the author undertook an active role in the analytic process. Themes did not emerge. Rather, they were generated through a reflexive process. |

### 3.4. Chapter Summary

This chapter has presented the methodology adopted for this study. It explained methodology as the overall logic that aligned the philosophical underpinnings and the choice of research paradigm, method, and techniques. The chapter then described the *design* of the study (Section 3.2). In so doing, it detailed the author's philosophical positions and how they informed his choices of research paradigm (*interpretivist*); method (*case study research*); and techniques for data collection (*semi-structured interviews*) and data analysis (*reflexive thematic analysis*) (Section 3.2). The chapter later also described the *conduct* of the study (Section 3.3), detailing the processes involved in the collection and analysis of the data. The chapter also explained how the author demonstrated rigour in the conduct of data analysis in line with the adopted framework for that purpose. Table 8 summarises the key elements in the design and conduct of the study.

Table 8. The summary of the key elements in the design and conduct of the study

| **Elements** | **Description of Elements** |
|---|---|
| Philosophical Assumptions | - *Ontology:* Reality is subjective and interpreted by individuals as social actors.<br>- *Epistemology:* Knowledge about reality can be acquired through subjective experience of that reality.<br>- *Logic:* Inferences about general principles can be made from particular instances.<br>- *Values:* Embedded in humans hence integrated with research (value-laden). |
| Research Paradigm | Interpretivist Paradigm |
| Research Method | Case Study Research |
| Research Techniques | Collection: Interviews (semi-structured) / Analysis: Thematic Analysis (reflexive) |
| Research Problem | Cognitive load in training on EMR systems (as a widespread form of HIT) |
| Research Questions | Of 'how' and 'why' nature |
| Unit of Analysis | Roles in training on an EMR system |
| Number of Cases | A single case study (as a unique and revelatory case for an in-depth analysis) |
| Use of Theory | Cognitive Load Theory as the theoretical lens (inductive) |
| Participating Organisation | A Neonatal Intensive Care Unit of a public hospital (Melbourne, Australia) |
| Sampling Strategy | Non-probabilistic (purposive / snowball sampling) |
| Participants | - Designers designed the instructional materials<br>- Trainers delivered the designed instructional materials<br>- Trainees trained using the same instructional materials |
| Ethics Committees Approvals | - Approved by the Participating Organisation's HREC (November 2018)<br>- Registered at Monash university's HREC (February 2019)<br>- Covered confidentiality of data, organisation, and participants' identity |

# CHAPTER FOUR

# RESULTS AND DISCUSSION

This chapter reports the findings of this study. It first provides a brief review of the analytical process from the previous chapter. It then presents the findings from this process in the form of three salient themes as well as three emergent findings from the data. Finally, the chapter discusses these findings and posits them in the extant literature on cognitive load and the broader area of Information Systems (IS).

## 4.1. Review of the Analytical Process

As discussed in Chapter Three, this study adopted a *reflexive approach* to thematic analysis of the data. This approach was guided by a framework suggested by Braun and Clarke (2006). The framework involved making six *decisions* prior to commencing the analysis, which determined its form and outcome (Section 3.3.2.2). In addition, the framework also involved following six *steps* during the analysis that guided the analytical process (Section 3.3.2.3). Ultimately, the analysis generated *three themes* repeating across the dataset.

Recalling from Chapter Two, this study suggested twelve techniques for three categories of cognitive load: (i) six techniques for reducing extraneous load; (ii) three for managing intrinsic load; and (iii) three for optimising germane load (Section 2.3.4). Given the volume of data generated on these techniques and the word limit sanctioned on this thesis, the use of data extracts to illustrate the presence of the themes is limited to one technique, namely Worked Example. The data extracts for other techniques are presented in the Codebook (Appendix H), which are discernible by their unique Data ID. These IDs consist of technique number (e.g., T1) followed by usage number (e.g., T1-U1), reason type and number (e.g., T1-R1-01) or effect type/subtype and number (T1-E1a-01). These Data IDs are used in this chapter in the figures, tables, and illustrative data extracts. The choice of Worked Example for this purpose lies in its significance to cognitive load research and theory. As stated earlier, worked examples help achieve what is known as the *Worked Example effect* (see 2.3.4.1.). According to Sweller et al. (2011a), not only is this effect "the most important of the cognitive load theory effects" (p. 108) but it has also influenced the theory itself by giving rise to several other effects. Some of these effects (e.g., Split-attention) are "critical to the effectiveness of worked examples" (p. 109). The relevant techniques to achieve these effects were listed in Table 2 (see the Related Techniques column).

## 4.2. The Findings

The analysis generated three salient themes and some emergent findings within the dataset. These comprised (i) preferred usage; (ii) rationale for usage; and (iii) perceived effects. These themes described (i) *which* techniques were preferred; (ii) *why* they were preferred; and (iii) *how* they were perceived to exert an effect. Together, these themes reflected the *participants' views* on the suggested techniques (see Sections 4.2.1 – 4.2.3). The other emergent findings reflected the participants' interpretation of cognitive load, their awareness of techniques and their views on a potentially new technique to manage cognitive load (see Section 4.2.4). These participants were the actors who played active roles in training on the EMR system at the Participating Organisation and comprised: (i) *Designers* who designed instructional or training materials for the system; (ii) *Trainers* who delivered training on the system using those materials; and (iii) *Trainees* who learned to use the system using the same materials. These findings are described in the subsequent pages.

### 4.2.1. Theme One: Preferred Usage

A recurring pattern across the dataset was the participants' *indications of preference* for using the techniques. This theme was labelled as *preferred usage* and captured the participants' preferred techniques for their EMR system training. These preferences *differed* between the participants, and were captured by two subthemes. The first subtheme, namely *CLT-congruent*, captured the preferences that were in congruence with cognitive load theory and research. The second subtheme, namely *CLT-incongruent*, by contrast, captured those in line with practices other than the theory and research on cognitive load (e.g., conventional practices).

The choice of names for the subthemes was based on the research tradition in CLT-informed instructional design. Since the early 1980s, cognitive load researchers have compared instructions which were *informed by CLT* with those *practised by conventions*. For example, Sweller and Cooper (1985) examined Worked Example as an alternative to conventional approaches to problem-solving such as means-end strategy. As described earlier (see Section 2.3.4.1), Worked Example provides learners with the solution to a problem in a *step-by-step* manner, rather than asking them to *search for the solution*. That being so, using steps to approach the problem-solution path is congruous with CLT, whereas asking learners to search for the solution is not. In relation to this study, this could be a participant who preferred using step-by-step to approach the problem-solution path as opposed to searching. This participant could be (i) a Designer who preferred to *demonstrate* the solutions in a 'step-by-step' manner while designing the instructions; (ii) a Trainer who preferred to *teach* the solutions in a 'step-by-step' manner while delivering the same instructions; and (iii) a Trainee who preferred to *learn* the solutions in a 'step-by-step' manner while learning from those instructions. These indications of preference are illustrated in Table 9 on the following page.

With respect to Worked Example for instance, three of nine participants (P02, P07, P09) preferred using step-by-step. By contrast, two participants (P03, P05) preferred searching for the solution instead:

> *"I would prefer if somebody gives you a solution step by step." (P02, Trainer, NS) (T1-U1)*
>
> *"I usually prefer to search for it." (P05, Trainee, NS) (T1-U2)*

These participants were specific about their preferences. They preferred either 'step-by-step' or 'search-for-solution' only (see T1-U1 and T1-U2 under Data ID in Table 9). Other participants, by contrast, preferred using both in conjunction with one another. One participant (P06), for example, preferred to start with steps and continue with searching on their own (T1-U3). S/he stated:

> *"I prefer a step-by-step, but then I need to go in." (P06, Trainee, MS) (T1-U3)*

The remaining three participants (P01, P04, P08), in contrast, preferred to start with searching, and if needed, use steps (T1-U4). These participants commonly pointed to difficulty in finding the solution as the condition for using steps.

> *"[…] they're asked to search for the solution themselves. And then, if they have difficulty finding it, then I would take them through step by step." (P01, Designer, MS) (T1-U4)*
>
> *"I prefer to search myself, and then, if I can't find it ask". (P04, Trainer, NS) (T1-U4)*
>
> *"I prefer to search for it myself but then, if I can't find it, be shown step by step by someone." (P08, Trainee, MS) (T1-U4)*

The same pattern appeared in the preferences indicated for almost all techniques. Some preferences were in line with CLT while others were in line with practices other than CLT. Those congruous with CLT are marked with an *asterisk* (*) in Table 9.

Table 9. Indications of preference for using the techniques

| **Category** | **Indications of preference** | **Data ID** | **Designers (n=2)** | **Trainers (n=2)** | **Trainees (n=5)** | **References (total)** |
|---|---|---|---|---|---|---|
| **Extraneous load** | **WORKED EXAMPLE** | **T1** | | | | **9** |
| | Using 'step-by-step' only* | T1-U1 | P07 | P02 | P09 | 3 |
| | Using 'search for solution' only | T1-U2 | | | P03, P05 | 2 |
| | Using 'step-by-step' followed by 'search for solution' | T1-U3 | | | P06 | 1 |
| | Using 'search for solution' followed by 'step-by-step' | T1-U4 | P01 | P04 | P08 | 3 |
| | **PROBLEM COMPLETION** | **T2** | | | | **9** |
| | Using 'partially-completed' examples* | T2-U1 | P01 | P02, P04 | P03, P09 | 5 |
| | Using 'non-completed' examples | T2-U2 | P07 | | P05, P06, P08 | 4 |
| | **SPLIT-ATTENTION** | **T3** | | | | **9** |
| | Using an 'integrated' source of information* | T3-U1 | P01, P07 | P02, P04 | P03, P05, P08, P09 | 8 |
| | Using 'separated' sources of information | T3-U2 | | | P06 | 1 |
| | **MODALITY** | **T4** | | | | **9** |
| | Using 'multimodal' presentation of information* | T4-U1 | P01, P07 | P02, P04 | P03, P05, P08, P09 | 8 |
| | Using 'unimodal' presentation of information | T4-U2 | | | P06 | 1 |
| | **TRANSIENT INFORMATION** | **T5** | | | | **9** |
| | Using 'non-transient' form of information* | T5-U1 | | P02, P04 | P05, P08, P09 | 5 |
| | Using 'transient' form of information | T5-U2 | | | P06 | 1 |
| | Using 'transient' and 'non-transient' forms of information | T5-U3 | P01, P07 | | P03 | 3 |
| | **REDUNDANCY** | **T6** | | | | **9** |
| | Using 'sufficient repetition' of information* | T6-U1 | P01, P07 | P02, P04 | P03, P05, P06, P08, P09 | 9 |
| **Intrinsic load** | **ISOLATED ELEMENTS** | **T7** | | | | **9** |
| | Using 'multiple' stages* | T7-U1 | P01, P07 | P02, P04 | P03, P08 | 6 |
| | Using 'single' stage | T7-U2 | | | P05, P06, P09 | 3 |

| Category | Indications of preference | Data ID | Designers (n=2) | Trainers (n=2) | Trainees (n=5) | References (total) |
|---|---|---|---|---|---|---|
| | **LOW- TO HIGH-PHYSICAL FIDELITY PROGRESSION** | **T8** | | | | **8**** |
| | Using 'low- to high-physical fidelity'* | T8-U1 | P01, P07 | P02, P04 | P05, P06 | 6 |
| | Using 'high-physical fidelity' | T8-U2 | | | P08, P09 | 2 |
| | **SIMPLE-TO-COMPLEX PROGRESSION** | **T9** | | | | **9** |
| | Using 'simple to complex' versions of a task* | T9-U1 | P07 | P02, P04 | P03, P05, P06, P08, P09 | 8 |
| | Using 'complex' version of a task | T9-U2 | P01 | | | 1 |
| **Germane load** | **VARIABILITY** | **T10** | | | | **9** |
| | Using 'high variability' for a task* | T10-U1 | | P02, P04 | P05, P06, P08, P09 | 6 |
| | Using 'low variability' for a task | T10-U2 | P01, P07 | | P03 | 3 |
| | **IMAGINATION** | **T11** | | | | **8**** |
| | Using 'imagination' to mentally rehearse a task* | T11-U1 | P01, P07 | P04 | P03, P05, P06, P09 | 7 |
| | Using no 'imagination' to mentally rehearse a task | T11-U2 | | | P08 | 1 |
| | **SELF-EXPLANATION** | **T12** | | | | **9** |
| | Using 'self-explanation' to prompt learning a task* | T12-U1 | P01, P07 | P02, P04 | P03, P05, P06, P08, P09 | 9 |

* Congruous with cognitive load theory and research.
** No indications of preference (P03 for T8; P02 for T11).

In this table, the first column *(Category)* shows the categories of cognitive load. The second column *(Indication of preference)* displays the indications of preference for each technique. The third column *(Data ID)* lists the data identifications, which uniquely identify the data for a technique (e.g., T1) and its associated preferences for usage (e.g., T1-U1 to T1-U4). The fourth through sixth columns *(Designers, Trainers, Trainees)* show the participants and their roles in training. The alphanumerical indicators in these columns represent the identifier for each participant (e.g., P07, P02, P09) who indicated a preference (e.g., T1-U1). The last column totals the number of references. These references represent the number of data coded to each participant. The bolded numbers at the top show the total references for each technique (e.g., a total of 9 references for T1). The numbers listed underneath show the subtotals of references for each indicated preference (e.g., a subtotal of 3 references for T1-U1). In this table, the number of references equals the number of participants in each associated usage (e.g., 3 references by 3 participants for T1-U1). This is because each participant indicated only one preference for each technique.

A closer look at Table 9 reveals the overall preferences for the suggested techniques. Figure 6, on the following page, illustrates the indicated preferences for all techniques in descending order. The bars represent the indications of preference, which darken in colour with more preferences.

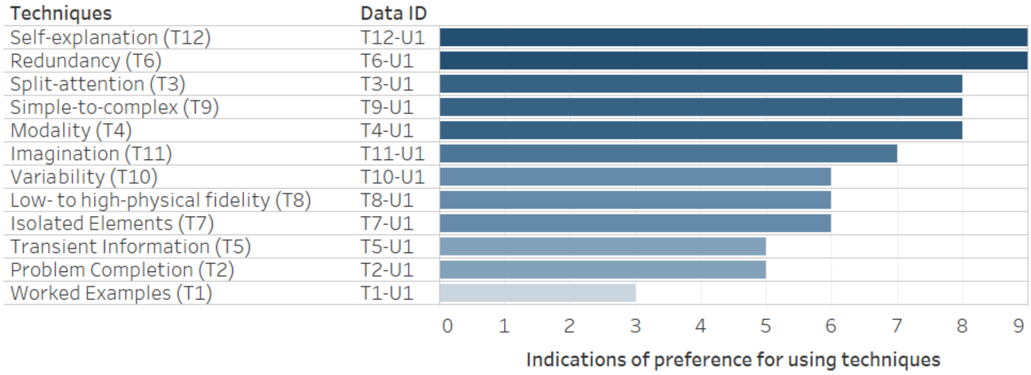


Figure 6. Indications of preference for using the techniques

A more detailed look at Table 9 also reveals the overall preferences for the techniques in different categories of cognitive load. Figure 7 presents these preferences in each category in descending order.

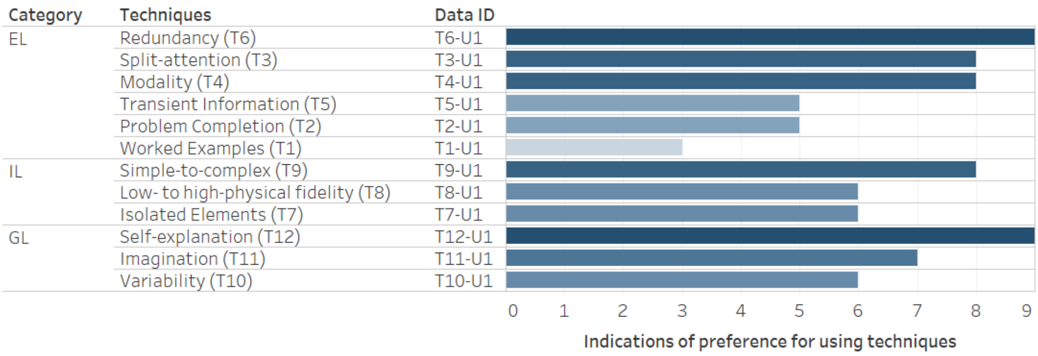


Figure 7. Indications of preference for using the techniques sorted by categories

As illustrated in Figure 7, in the first category (EL), Redundancy (T6) was most preferred. All participants indicated a preference for this technique (9 of 9). Split-attention (T3) and Modality (T4) followed with *almost all* participants (8 of 9 approx. 89%). In this category, Worked Example (T1) was least preferred with only three participants preferring it (3 of 9 approx. 33%). Problem Completion (T2) and Transient Information (T5) followed with five of nine participants (approx. 56%). In the second category (IL), Simple-to-complex (T9) was most preferred by *almost all* participants (8 of 9). Low- to high-physical fidelity (T8) and Isolated Elements (T7) followed both with six of nine participants (approx. 67%, each). In the third category (GL), Self-explanation (T12) was most preferred by *all* participants (9 of 9). This was followed by Imagination (T11) and Variability (T10) with seven and six participants, respectively (approx. 78% and 67%). Table 10 shows which participant, in which role, indicated a preference for the techniques.

Table 10. Indications of preference for using techniques sorted by actors

| Categories | Techniques | Data ID | Trainers | | Designers | | Trainees | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | P02 | P04 | P01 | P07 | P03 | P05 | P06 | P08 | P09 | (n of 9) |
| EL | Redundancy (T6) | T6-U1 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | 9 |
| | Split-attention (T3) | T3-U1 | ○ | ○ | ○ | ○ | ○ | ○ | | ○ | ○ | 8 |
| | Modality (T4) | T4-U1 | ○ | ○ | ○ | ○ | ○ | ○ | | ○ | ○ | 8 |
| | Transient Information (T5) | T5-U1 | ○ | ○ | | | | ○ | | ○ | ○ | 5 |
| | Problem Completion (T2) | T2-U1 | ○ | ○ | ○ | | ○ | | | | ○ | 5 |
| | Worked Example (T1) | T1-U1 | ○ | | | ○ | | | | | ○ | 3 |
| IL | Simple-to-complex (T9) | T9-U1 | ○ | ○ | | ○ | ○ | ○ | ○ | ○ | ○ | 8 |
| | Low- to high-physical fidelity (T8) | T8-U1 | ○ | ○ | ○ | ○ | | ○ | ○ | | | 6 |
| | Isolated Elements (T7) | T7-U1 | ○ | ○ | ○ | ○ | ○ | | | ○ | | 6 |
| GL | Self-explanation (T12) | T12-U1 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | 9 |
| | Imagination (T11) | T11-U1 | | ○ | ○ | ○ | ○ | ○ | ○ | | ○ | 7 |
| | Variability (T10) | T10-U1 | ○ | ○ | | | | ○ | ○ | ○ | ○ | 6 |
| | Total (n of 12) | | 11 | 11 | 8 | 9 | 8 | 9 | 6 | 8 | 10 | |

As illustrated in Table 10, the participants showed different preferences for different techniques. The Trainers indicated *a strong preference* for the suggested techniques. On average, Trainers preferred eleven of the twelve techniques (approx. 92%) for delivering the instructional materials. The Designers' preference appeared *less strong* than that of Trainers. Their average preference was 8.5 of twelve techniques (approx. 71%) for designing the instructional materials. The Trainees preference appeared *slightly weaker* than that of Designers. They preferred, on average, 8.2 techniques (approx. 69%) for learning the instructional materials in their training.

#### 4.2.2. Theme Two: Rationale for Usage

Another recurring pattern in the dataset involved the participants' *indications of reasons* for using the techniques. These indications reflected their *rationale for usage*, which was captured by the second theme. Whereas the first theme described *which* techniques were preferred, the second theme described *why* they were preferred. Similar to the indicated preferences, the cited reasons also differed for using the techniques. For example, with respect to Worked Example (T1), the participants explained their preferences for the step-by-step approach to the problem-solution path. They believed that such an approach could help 'build self-confidence' (T1-R1-03) or makes it 'easier to get direction' (T1-R1-05):

*"I've already got the steps, you know. […] If you feel comfortable or confident that you know you followed the instructions correctly, you're more likely to go back and want to do it again and think: Yes, I can learn this." (P02, Trainer, NS) (T1-R1-03)*

*"It's probably easier. If you have a question about how to do something, it's easier if there is [something] or someone who's able to show you step by step how to do it, rather than having to start from scratch and look for a solution." (P09, Trainee, MS) (T1-R1-05)*

In contrast, other participants (P03, P05) explained their preference for searching. These participants insisted that searching could allow them to 'get involved and explore' (T1-R2-01) on their own:

*"Yeah, well I mean it's better to be uh, what's the term for it, it's better to be a little bit more proactive in doing the work yourself, rather than to be told. Because if you get told the next time you may or may not retain that information. So, I am of the firm belief that if you do it yourself once you tend to remember it." (P03, Trainee, MS) (T1-R2-01)*

*"I usually prefer to search for it. I like to sort of play, […]. Actually, you know, troubleshoot and work through a problem to try and come [up] with a solution." (P05, Trainee, NS) (T1-R2-01)*

Other participants who preferred to approach the problem-solution path using *both steps and searching* in conjunction with one another indicated other reasons. The participant (P06) who preferred to start with steps and continue with searching (T1-U3) indicated a similar reason to the above-mentioned participants (P03, P05). S/he pointed to 'getting involved and explore' (T1-R3-01) by searching for the solution:

*"[…] I prefer step-by-step, but then I need to go in. The way I learn is I need to do it myself after that. […] for me no matter how many times someone shows me the particular way, I need to actually spend time and I guess have my own way of finding things." (P06, Trainee, NS) (T1-R3-01)*

Other participants who preferred to start with searching, and if needed, continued with steps reasoned differently. One participant (P01), for example, pointed to the 'troubleshooting' property (T1-R4-02) of this approach (T1-U4) and stated:

*"[…] I think more helpful. Because usually it's troubleshooting. I've used this technique for a few years now – three or four years, even five years." (P01, Designer, MS) (T1-R4-02)*

The other participants (P04, P08), in contrast, pointed to the 'playing and exploring' characteristics (T1-R4-01) of this approach. They commented:

*"What I found I learn much better playing, looking, and searching. And then if I really can't find the solution." (P04, Trainer, NS) (T1-R4-01)*

*"I think if I work it out for myself, then I remember it better. How I did it, to do it again the next time." (P08, Trainee, MS) (T1-R4-01)*

This pattern appeared across other techniques and is illustrated in Table 11.

Table 11. Indications of reasons for using the techniques

| Category | Indications of reasons for using techniques | Data ID | Designers (n=2) | Trainers (n=2) | Trainees (n=5) | References (total) |
|---|---|---|---|---|---|---|
| **Extraneous load** | **WORKED EXAMPLE** | **T1** | | | | **9** |
| | Synchronises trainer-trainee pace | T1-R1-01 | P07 | | | 1 |
| | Leads to outcome | T1-R1-02 | | P02 | | 1 |
| | Builds self-confidence | T1-R1-03 | | P02 | | 5 |
| | Saves time | T1-R1-04 | | P02 | | 1 |
| | Easier to get direction | T1-R1-05 | | | P09 | 1 |
| | **PROBLEM COMPLETION** | **T2** | | | | **5** |
| | Leads to outcome | T2-R1-01 | P01 | | | 1 |
| | Improves attentiveness | T2-R1-02 | | P02, P04 | P03, P09 | 4 |
| | **SPLIT-ATTENTION** | **T3** | | | | **11** |
| | Helps seeing the link | T3-R1-01 | P01 | P02, P04 | P03, P08, P09 | 8 |
| | Helps understanding information as a whole | T3-R1-02 | P07 | | P05 | 3 |
| | **MODALITY** | **T4** | | | | **9** |
| | Helps focus better | T4-R1-01 | P01 | | P05 | 2 |
| | Helps retain better | T4-R1-02 | P07 | P02 | P09 | 3 |
| | Helps reinforce learning | T4-R1-03 | | P02, P04 | P03, P08 | 4 |
| | **TRANSIENT INFORMATION** | **T5** | | | | **6** |
| | Allows revisiting the materials | T5-R1-01 | | P02, P04 | P05, P08, P09 | 6 |
| | **REDUNDANCY** | **T6** | | | | **14** |
| | Helps reinforce learning | T6-R1-01 | P01, P07 | P02, P04 | P05, P06, P09 | 11 |
| | Helps retain better | T6-R1-02 | | P02 | P03, P08 | 3 |
| **Intrinsic load** | **ISOLATED ELEMENTS** | **T7** | | | | **11** |
| | Makes explanation easier | T7-R1-01 | P01, P07 | P02 | | 4 |
| | Makes understanding easier | T7-R1-02 | P01, P07 | P02, P04 | P03, P08 | 7 |
| | **LOW- TO HIGH-PHYSICAL FIDELITY PROGRESSION** | **T8** | | | | **11** |
| | Allows to build-up | T8-R1-01 | P01, P07 | P02, P04 | P06 | 7 |
| | Allows to practice in real time | T8-R1-02 | P01 | | P05 | 4 |
| | **SIMPLE-TO-COMPLEX PROGRESSION** | **T9** | | | | **11** |
| | Allows to build-up | T9-R1-01 | | P04 | P05, P06, P08, P09 | 5 |
| | Makes understanding easier | T9-R1-02 | P07 | P02 | P03, P05, P09 | 6 |
| **Germane load** | **VARIABILITY** | **T10** | | | | **12** |
| | Makes understanding easier | T10-R1-01 | | P02, P04 | P05, P06 | 7 |
| | Allows to see it from different angles | T10-R1-02 | | | P05, P06, P08, P09 | 5 |
| | **IMAGINATION** | **T11** | | | | **9** |
| | Allows to think it through | T11-R1-01 | P01, P07 | P04 | P03, P05, P06, P09 | 9 |
| | **SELF-EXPLANATION** | **T12** | | | | **10** |
| | Allows getting a deeper understanding | T12-R1-01 | | P02, P04 | P06, P09 | 4 |
| | Allows to talk themselves through | T12-R1-02 | | | P05, P06, P08, P09 | 5 |
| | Allows for an overall view | T12-R1-03 | | | P03 | 1 |

As illustrated in Table 11, the participants indicated different reasons for using the techniques for their training. The degree to which these reasons varied were different for each technique. Note that this table only presents the reasons for preferences that were in line with CLT. The other reasons are listed in the Codebook (Appendix H). Figure 8 presents this set of reasons for using each technique in descending order. Similar to the previous figures, the bars with darker colours represent more indications of their associated reasons.

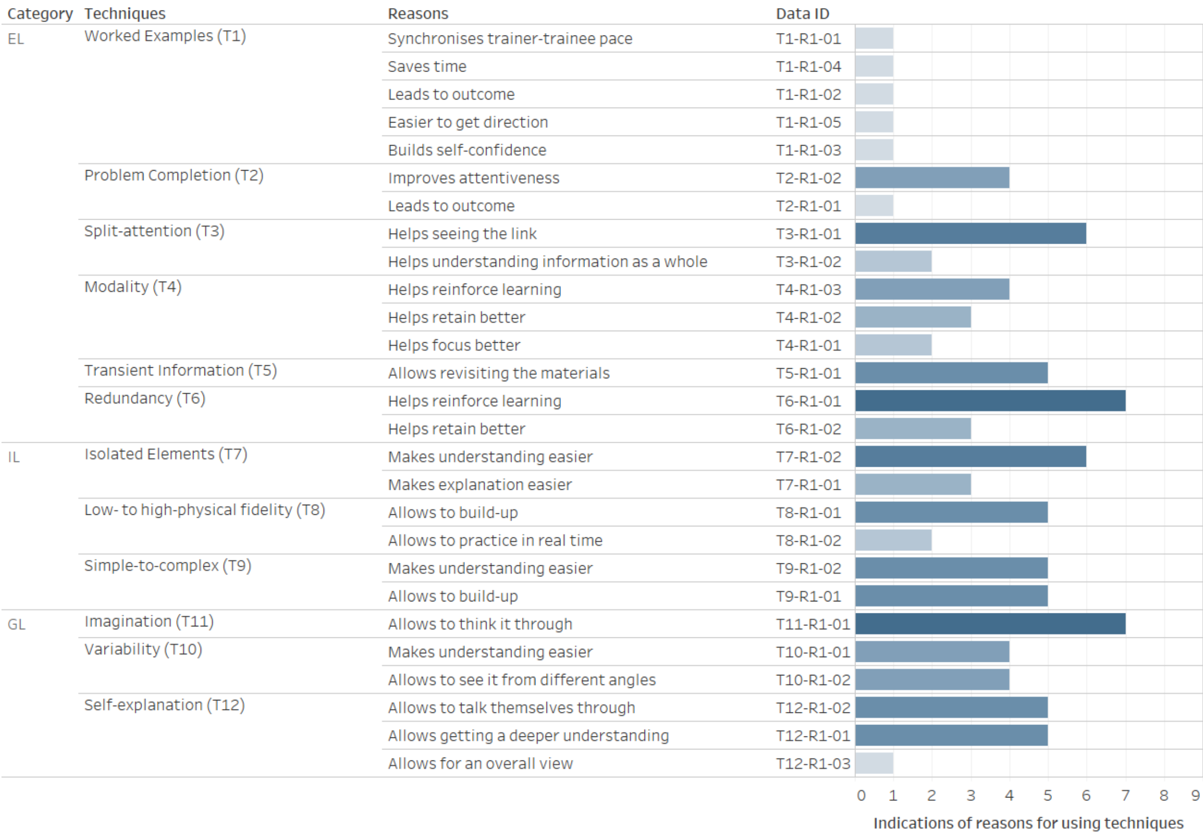


Figure 8. Indications of reasons for using the techniques sorted by categories

As presented in Figure 8, the participants indicated different reasons for using the techniques. For some techniques, they had some degree of unanimity (e.g., Imagination), while for other techniques they had none (e.g., Worked Example). For most techniques, however, they differed from one another to a different extent. For example, for Simple-to-complex (T9), the participants indicated two reasons with an equal number for each reason (i.e., five each). In contrast, for Split-attention (T3), they also indicated two reasons but with a different number for each reason (i.e., six and two).

Table 12 illustrates which participant, in which role, indicated a reason for using each technique.

Table 12. Indications of reasons for using the techniques sorted by actors

| Categories | Reasons | Data ID | Trainers | | Designers | | Trainees | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | P02 | P04 | P01 | P07 | P03 | P05 | P06 | P08 | P09 | (n of 9) |
| EL | Synchronises trainer-trainee pace | T1-R1-01 | | | | ○ | | | | | | 1 |
| | Leads to outcome | T1-R1-02 | ○ | | | | | | | | | 1 |
| | Builds self-confidence | T1-R1-03 | ○ | | | | | | | | | 1 |
| | Saves time | T1-R1-04 | ○ | | | | | | | | | 1 |
| | Easier to get direction | T1-R1-05 | | | | | | | | | ○ | 1 |
| | Leads to outcome | T2-R1-01 | | | ○ | | | | | | | 1 |
| | Improves attentiveness | T2-R1-02 | ○ | ○ | | | ○ | | | | ○ | 4 |
| | Helps seeing the link | T3-R1-01 | ○ | ○ | ○ | | ○ | | | ○ | ○ | 4 |
| | Helps understanding info. as a whole | T3-R1-02 | | | | ○ | | ○ | | | | 2 |
| | Helps focus better | T4-R1-01 | | | ○ | | | ○ | | | | 2 |
| | Helps retain better | T4-R1-02 | ○ | | | ○ | | | | | ○ | 3 |
| | Helps reinforce learning | T4-R1-03 | ○ | ○ | | | ○ | | | ○ | | 4 |
| | Allows revisiting the materials | T5-R1-01 | ○ | ○ | | | | ○ | | ○ | ○ | 5 |
| | Helps reinforce learning | T6-R1-01 | ○ | ○ | ○ | ○ | | ○ | ○ | | ○ | 7 |
| | Helps retain better | T6-R1-02 | ○ | | | | ○ | | | ○ | | 3 |
| IL | Makes explanation easier | T7-R1-01 | ○ | | ○ | ○ | | | | | | 3 |
| | Makes understanding easier | T7-R1-02 | ○ | ○ | ○ | ○ | ○ | | | ○ | | 6 |
| | Allows to build-up | T8-R1-01 | ○ | ○ | ○ | ○ | | | ○ | | | 5 |
| | Allows to practice in real time | T8-R1-02 | | | ○ | | | ○ | | | | 2 |
| | Allows to build-up | T9-R1-01 | | ○ | | | | ○ | ○ | ○ | ○ | 5 |
| | Makes understanding easier | T9-R1-02 | ○ | | | ○ | ○ | ○ | | | ○ | 5 |
| GL | Makes understanding easier | T10-R1-01 | ○ | ○ | | | | ○ | ○ | | | 4 |
| | Allows to see it from different angles | T10-R1-02 | | | | | | ○ | ○ | ○ | ○ | 4 |
| | Allows to think it through | T11-R1-01 | | ○ | ○ | ○ | ○ | ○ | ○ | | ○ | 7 |
| | Allows getting a deeper understanding | T12-R1-01 | ○ | ○ | | | | | ○ | | ○ | 4 |
| | Allows to talk themselves through | T12-R1-02 | | | | | | ○ | ○ | ○ | ○ | 4 |
| | Allows for an overall view | T12-R1-03 | | | | | ○ | | | | | 1 |
| | Total (n of 27) | | 16 | 11 | 9 | 9 | 8 | 11 | 8 | 8 | 12 | |

### 4.2.3. Theme Three: Perceived Effects

Another pattern recurring in the dataset involved *indications of effects* perceived in using the techniques. This pattern was captured by the third theme, namely *Perceived effects*. This theme reflected the participants' *perception of effects* and described *how* the techniques were perceived to exert an effect in terms of (i) learning; (ii) learning style; (iii) expertise level; and (iv) context. Similar to preferences and reasons, the participants also indicated different effects. Referring to Worked Example (T1), statements similar to the following reflected their perceived effects on *learning* (T1-E1):

> *"I think, if you get that and then you follow that and you think you want some more, you can then go on look yourself. […] The more solutions to give to people and the more confident they feel, the more likely they want to learn it and to teach other people, and you know, go away feeling comfortable and confident." (P02, Trainer, NS) (T1-E1a-02)*

These participants pointed to how they thought this technique could help their learning. A participant (P02), for instance, pointed to 'returning for more examples' (T1-E1a-02) due to more confidence. Other participants, however, had different perceptions. Those who did not prefer using steps (P03, P05), for example, raised an interesting point. They pointed to better learning with searching for solutions by 'being actively involved in learning' (T1-E1b-01). They stated:

> *"You get better at retaining the information or the steps towards the solution, if you have performed those steps yourself." (P03, Trainee, MS) (T1-E1b-01)*

> *"I can't focus as well when someone is just telling me or showing me something. I sort of have to focus on what they're doing. Whereas if I'm doing it, I can I guess learn what I'm doing more than having to focus on something else." (P05, Trainee, NS) (T1-E1b-01)*

Other participants who preferred using both *steps and searching* indicated other effects on learning. The participant (P06) who preferred to start with steps and continue with searching had a similar perception to the participants mentioned above (P03, P05). S/he preferred being guided first but pointed to being active in learning 'by delving in' (T1-E1c-01) the problem:

> *"I think people can show me, so I'd need to see it visually as to what I'm trying to achieve. But then for me no matter how many times someone shows me the particular way, I need to actually spend time and I guess have my own way of finding things. I guess, it's my little pathway to finding out the answer. But the more I kind of play with it, then it becomes more natural for me." (P06, Trainee, NS) (T1-E1c-01)*

Others who preferred to start with searching and continued with steps when needed had a similar perception (P01, P04, P08). They also pointed to 'being more involved' (T1-E1d-01) when searched for the solution:

*"Because I've worked through it myself, because I've done the clicks myself. It then embeds in because I've discovered the answer myself, rather than somebody just saying click here, click here, type here." (P04, Trainer, NS) (T1-E1d-01)*

*"I think if I work it out for myself, then I remember it better. How I did it, to do it again the next time." (P08, Trainee, MS) (T1-E1d-01)*

In addition, some participants also reckoned that the effects could be based on 'learning style' (T1-E2). Among them, one participant (P07) aptly remarked:

*"Oh, I suppose all depends [on] how people learn. […] I did the step-by-step, and I think both helped people depends on what type of learner you are. […] I mean some people like rules and they just go from one to the other. That's who they are, their real focus. But other people are quite more exploratory. They know if they press this button and the system's not going to crash. […] But others are more adventurous and problem solvers. Some will find a way to find themselves." (P07, Designer, NS) (T1-E2-01)*

Some participants also recognised the effects based on learners' expertise level (T1-E3). They commonly linked using steps to 'novice learners' and searching to 'expert learners' and stated:

*"The novice probably sticks to the rules." (P07, Designer, NS) (T1-E3-01)*

*"I think it's asked them, to give them [experts] problem and ask them to solve themselves. […] I think it's the memory of prior learning and memory. And I think, it is they usually remember something from before." (P01, Designer, MS) (T1-E3-02)*

Other participants raised another interesting point. They looked on the effects from a contextual perspective in terms of the environment and system (T1-E4). One participant (P03), in particular, considered using step-by-step as unsuitable for systems with 'intuitive designs' (T1-E4b-01):

*"I think someone needs to tell you the very basic things. Show you the very basic, like the layout. But again, [system name removed] is a system that I feel is very easy to navigate most of the time. Like I said before, some things are not very intuitive, but if I was completely new to [system name removed], I could open it up and I think I could access a patient's information in quite a straightforward way." (P03, Trainee, MS) (T1-E4b-01)*

Table 13, in the following page, presents the indications of effects. Note the differences in the Data IDs representing the effects in terms of learning (T1-E1); learning style (T1-E2); expertise level (T1-E3); and context (T1-E4). Similar to Table 11, this table also presents the effects perceived for the preferred usages that were in line with CLT. The other effects are listed in the Codebook (Appendix H).

Table 13. The perceived effects of using the techniques

| Category | Indications of effects perceived in using techniques | Data ID | Designers (n=2) | Trainers (n=2) | Trainees (n=5) | References (total) |
|---|---|---|---|---|---|---|
| **Extraneous load** | **WORKED EXAMPLE** | **T1** | | | | **20** |
| | By preventing mismatch in teaching-learning process | T1-E1a-01 | P07 | | | 1 |
| | By returning for more examples | T1-E1a-02 | | P02 | | 3 |
| | By checking mistakes in earlier steps | T1-E1a-03 | | P02 | | 1 |
| | By being guided when needed | T1-E1a-04 | | | P09 | 1 |
| | By considering the learning style | T1-E2-01 | P07 | P04 | P03, P05, P06 | 10 |
| | By targeting novice learners | T1-E3-01 | P07 | | | 1 |
| | By using for high-stress environment | T1-E4a-01 | | P02 | | 2 |
| | By not using for intuitive systems | T1-E4b-01 | | | P03 | 1 |
| | **PROBLEM COMPLETION** | **T2** | | | | **10** |
| | By spending more time | T2-E1a-01 | P01 | | | 1 |
| | By being more engaged | T2-E1a-02 | | P02, P04 | P03, P09 | 5 |
| | Suitable for novice learners | T2-E3-01 | P01 | P02 | | 3 |
| | Not suitable for expert learners | T2-E3-02 | | P02 | | 1 |
| | **SPLIT-ATTENTION** | **T3** | | | | **10** |
| | By avoiding unnecessary processing | T3-E1a-01 | P01 | | P08 | 2 |
| | By getting the full picture | T3-E1a-02 | | P02, P04 | P05, P09 | 4 |
| | By helping to make sense | T3-E1a-03 | P07 | | P03, P05 | 4 |
| | **MODALITY** | **T4** | | | | **15** |
| | By linking audio and visual contents | T4-E1a-01 | P01 | P04 | P03, P05 | 4 |
| | By remembering information | T4-E1a-02 | P07 | P02 | P08, P09 | 4 |
| | Some prefer auditory only | T4-E2-01 | | P02 | P03 | 2 |
| | Some prefer visual only | T4-E2-02 | | P02 | P03, P06 | 5 |
| | **TRANSIENT INFORMATION** | **T5** | | | | **6** |
| | By being able to go through the materials | T5-E1a-01 | | P02, P04 | P05, P08, P09 | 6 |
| | **REDUNDANCY** | **T6** | | | | **11** |
| | By seeing different aspects of information | T6-E1a-01 | P07 | P02, P04 | | 3 |
| | By avoiding repetitiveness | T6-E1a-02 | P07 | P02 | P03, P05, P06, P08, P09 | 7 |
| | By having repeating in a regular basis | T6-E1a-03 | P01 | | P03 | 1 |
| **Intrinsic load** | **ISOLATED ELEMENTS** | **T7** | | | | **9** |
| | By enabling progression | T7-E1a-01 | P01, P07 | P02, P04 | P03 | 5 |
| | By showing the big picture first | T7-E1a-02 | | P02, P04 | P08 | 3 |
| | Helpful for complex EMR systems | T7-E4-01 | | | P03 | 1 |
| | **LOW- TO HIGH-PHYSICAL FIDELITY PROGRESSION** | **T8** | | | | **9** |
| | By enabling progression | T8-E1a-01 | P01, P07 | P02, P04 | P06 | 5 |
| | By showing the big picture first | T8-E1a-02 | | P02 | | 2 |
| | By seeing the reality of situation gradually | T8-E1a-03 | | | P05 | 2 |
| | **SIMPLE-TO-COMPLEX PROGRESSION** | **T9** | | | | **11** |
| | By enabling progression | T9-E1a-01 | | P02, P04 | P03, P06, P08, P09 | 6 |
| | By showing the big picture first | T9-E1a-02 | | P04 | P05, P08 | 3 |
| | Depends on learning style | T9-E2-01 | P07 | | P03 | 2 |
| **Germane load** | **VARIABILITY** | **T10** | | | | **7** |
| | By giving options to choose from | T10-E1a-01 | | P02, P04 | P06, P08 | 4 |
| | By allowing to compare variations | T10-E1a-02 | | | P05, P08, P09 | 3 |
| | Depends on learning style | T10-E2-01 | | P02, P04 | P06 | 5 |
| | **IMAGINATION** | **T11** | | | | **9** |
| | By enabling mental rehearsal | T11-E1a-01 | P01, P07 | P04 | P03, P05, P06, P09 | 9 |
| | **SELF-EXPLANATION** | **T12** | | | | **9** |
| | By identifying one's knowledge gap | T12-1Ea-01 | | P02, P04 | P03 | 3 |
| | By stimulating the brain | T12-1Ea-02 | P01, P07 | | P05, P06, P08, P09 | 6 |

The perceived effects of using the techniques are presented in Figure 9. Similar to other figures, the bars with darker colours represent a greater number of indications.

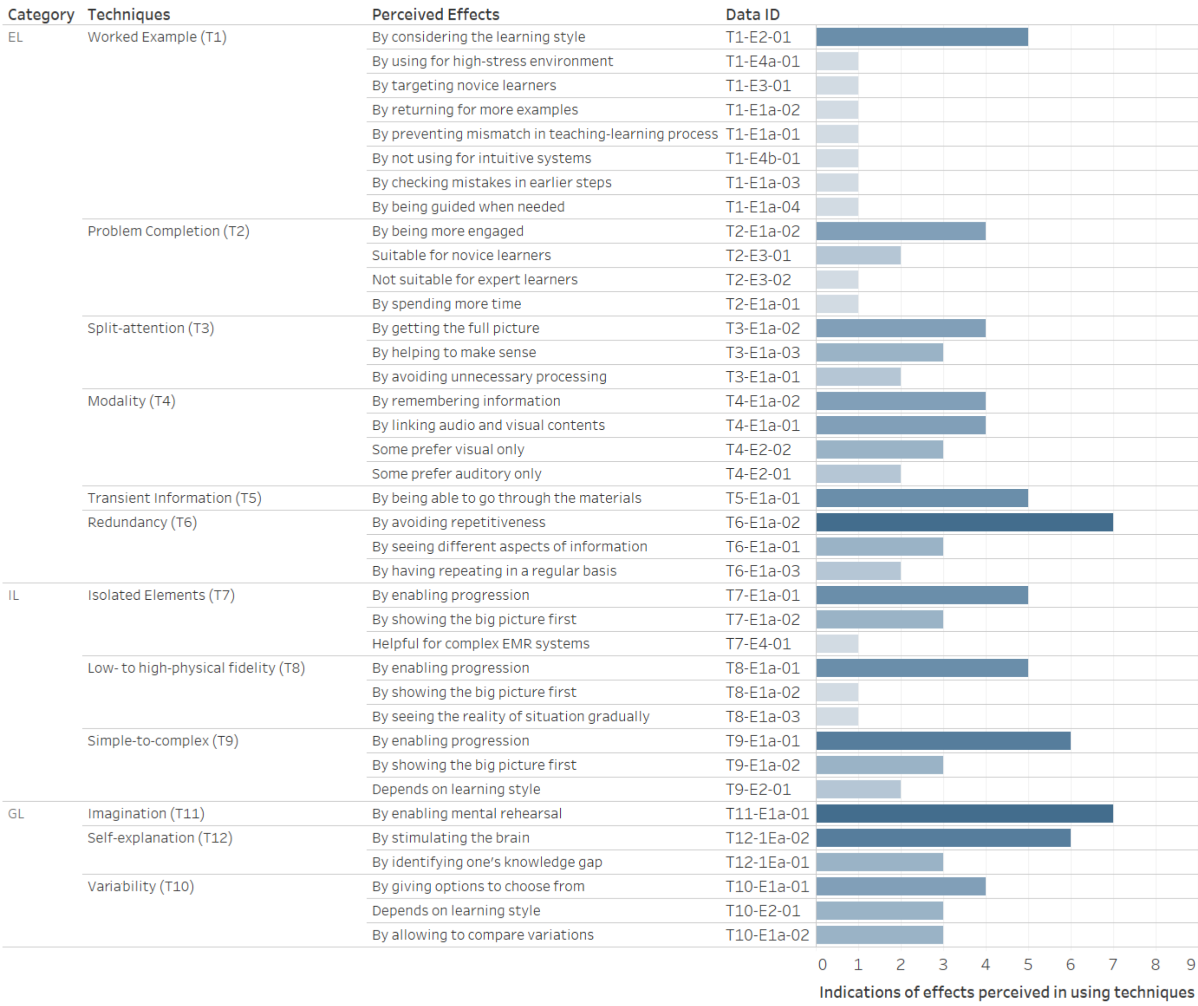


Figure 9. Perceived effects of using the techniques sorted by categories

As presented in Figure 9, the participants perceived different effects of using the techniques. For some techniques, they had some degree of unanimity in their perception (e.g., Imagination, *T11*). For most techniques, however, they differed from one another to a varying extent. For example, for Simple-to-complex (T9), the participants perceived three effects but showed a greater degree of unanimity for one effect (e.g., T9-E1a-01). In contrast, for Split-attention (T3), they also perceived three effects but with less unanimity (e.g., spread among the three effects). Table 14, on the following page, illustrates which participant, in which role, perceived an effect in using each technique.

Table 14. Perceived effects of using the techniques sorted by actors

| Categories | Reasons | Data ID | Trainers | | Designers | | Trainees | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | P02 | P04 | P01 | P07 | P03 | P05 | P06 | P08 | P09 | (n of 9) |
| EL | By preventing mismatch in teaching-learning | T1-E1a-01 | | | | ○ | | | | | | 1 |
| | By returning for more examples | T1-E1a-02 | ○ | | | | | | | | | 1 |
| | By checking mistakes in earlier steps | T1-E1a-03 | ○ | | | | | | | | | 1 |
| | By being guided when needed | T1-E1a-04 | | | | | | | | | ○ | 1 |
| | By considering the learning style | T1-E2-01 | | ○ | | ○ | ○ | ○ | ○ | | | 5 |
| | By targeting novice learners | T1-E3-01 | | | | ○ | | | | | | 1 |
| | By using for high-stress environment | T1-E4a-01 | ○ | | | | | | | | | 1 |
| | By not using for intuitive systems | T1-E4b-01 | | | | | ○ | | | | | 1 |
| | By spending more time | T2-E1a-01 | | | ○ | | | | | | | 1 |
| | By being more engaged | T2-E1a-02 | ○ | ○ | | | ○ | | | | ○ | 4 |
| | Suitable for novice learners | T2-E3-01 | ○ | | ○ | | | | | | | 2 |
| | Not suitable for expert learners | T2-E3-02 | ○ | | | | | | | | | 1 |
| | By avoiding unnecessary processing | T3-E1a-01 | | | ○ | | | | | ○ | | 2 |
| | By getting the full picture | T3-E1a-02 | ○ | ○ | | | | ○ | | | ○ | 4 |
| | By helping to make sense | T3-E1a-03 | | | | ○ | ○ | ○ | | | | 3 |
| | By linking audio and visual contents | T4-E1a-01 | | ○ | ○ | | ○ | ○ | | | | 4 |
| | By remembering information | T4-E1a-02 | ○ | | | ○ | | | | ○ | ○ | 5 |
| | Some prefer auditory only | T4-E2-01 | ○ | | | | ○ | | | | | 2 |
| | Some prefer visual only | T4-E2-02 | ○ | | | | ○ | | ○ | | | 3 |
| | By being able to go through materials | T5-E1a-01 | ○ | ○ | | | | ○ | | ○ | ○ | 5 |
| | By seeing different aspects of info | T6-E1a-01 | ○ | ○ | | ○ | | | | | | 3 |
| | By avoiding repetitiveness | T6-E1a-02 | ○ | | | ○ | ○ | ○ | ○ | ○ | ○ | 7 |
| | By having repeating in a regular basis | T6-E1a-03 | | | ○ | | ○ | | | | | 2 |
| IL | By enabling progression | T7-E1a-01 | ○ | ○ | ○ | ○ | ○ | | | | | 5 |
| | By showing the big picture first | T7-E1a-02 | ○ | ○ | | | | | | ○ | | 3 |
| | Helpful for complex EMR systems | T7-E4-01 | | | | | ○ | | | | | 3 |
| | By enabling progression | T8-E1a-01 | ○ | ○ | ○ | ○ | | | ○ | | | 5 |
| | By showing the big picture first | T8-E1a-02 | ○ | | | | | | | | | 1 |
| | By seeing the reality of situation gradually | T8-E1a-03 | | | | | | ○ | | | | 1 |
| | By enabling progression | T9-E1a-01 | ○ | ○ | | | ○ | | ○ | ○ | ○ | 6 |
| | By showing the big picture first | T9-E1a-02 | | ○ | | | | ○ | | ○ | | 3 |
| | Depends on learning style | T9-E2-01 | | | | ○ | ○ | | | | | 2 |
| GL | By giving options to choose from | T10-E1a-01 | ○ | ○ | | | | | ○ | ○ | | 4 |
| | By allowing to compare variations | T10-E1a-02 | | | | | | ○ | | ○ | ○ | 3 |
| | Depends on learning style | T10-E2-01 | ○ | ○ | | | | | ○ | | | 3 |
| | By enabling mental rehearsal | T11-E1a-01 | | ○ | ○ | ○ | ○ | ○ | ○ | | ○ | 7 |
| | By identifying one's knowledge gap | T12-E1a-01 | ○ | ○ | | | ○ | | | | | 3 |
| | By stimulating the brain | T12-E1a-02 | | | ○ | ○ | | ○ | ○ | ○ | ○ | 6 |
| | Total (n of 38) | | 21 | 15 | 9 | 12 | 15 | 11 | 9 | 10 | 10 | |

### 4.2.4. Other Emergent Findings

In addition to the themes presented earlier, three interesting points stood out in the dataset. First, the participants' *interpretation* of cognitive load. Second, their *awareness* of techniques for managing cognitive load.[2] Third, their views on a *potentially new technique* for optimising germane load.

[2] The first two of three emergent findings were presented at the 30th Australasian Conference on Information Systems (ACIS' 2019) in Perth, Australia.

Cognitive load was interpreted as *a recognised phenomenon*. Regardless of their roles, the participants' accounts of cognitive load indicated an in-depth understanding. In most cases, they had a shared experience of this phenomenon. Designers, for example, 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 (treatments and interventions). They 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." (P01, Designer, MS)*
>
> *"To me, cognitive load is how much information you take in, process, access, and then to be able to use. […] at times I feel that I have cognitive overload where I need to pause to draw on the memory of what I know." (P07, Designer, NS)*

Trainers and Trainees associated cognitive load with (i) stress; and (ii) information overload. Their statements were similar to the following:

> *"[…] 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." (P02, Trainer, NS)*
>
> *"Yeah, when I take so much information in at a time. And then, the rest of the information either isn't absorbed or is forgotten." (P04, Trainer, NS)*
>
> *"[…] 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." (P08, Trainee, MS)*
>
> *"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." (P05, Trainee, NS)*

Many participants recognised the *impairing effect* of cognitive load on learning. They commonly pointed to 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." (P01, Designer, MS)*
>
> *"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." (P02, Trainer, NS)*

> *"[…] 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." (P03, Trainee, MS)*

Similarly, some participants also recognised the cognitive load that is imposed by the instructional materials. They pointed to a *disconnect with the contents* and generally attributed it to the complexity of 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." (P08, Trainee, MS)*
>
> *"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." (P04, Trainer, NS)*

Nevertheless, it was noticeable that the participants were not aware of the techniques for managing cognitive load. This included *all* Designers and Trainers and *almost all* Trainees who, in some instances, even sounded surprised when they were asked if they knew about the techniques that are specifically designed to manage cognitive load imposed by instructional materials:

> *"No, I wasn't aware of that." (P01, Designer, MS)*
>
> *"Oh right! No, I didn't know that." (P07, Designer, NS)*
>
> *"Probably not, really." (P02, Trainer, NS)*
>
> *"Not formal ones. No." (P04, Trainer, NS)*
>
> *"No! [sounded surprised]." (P03, Trainee, MS)*
>
> *"Um, no, I'm not aware of any." (P09, Trainee, MS)*

Surprisingly, only one participant, a Trainee (P08), claimed to know about these techniques. The domain that informed the participant's knowledge is worth considering (i.e. *Education*, the birthplace of CLT):

> *"Yes, the rest of my family work in education [emphasis added]. I've heard about that sort of stuff from them." (P08, Trainee, MS)*

The other point that stood out involved the notion of *explaining a concept to others rather than self* to facilitate learning. This notion was first discussed in the interview with the first participant and repeatedly conferred with other participants. In total, seven out of seven participants who were questioned on this notion pointed to an *enhancing effect* of *peer-to-peer explanation* on learning. Three participants, in particular, pointed to the identification of their *knowledge gap* while explaining a concept to their peers. For example:

> *"Once you teach something to somebody else, you teach it back to yourself." (P07, Designer, NS)*

> *"Yeah, because if [I] understood it fully, then I should be able to show you how to do it. And, if I then struggled to show you how to do it, then so that I need to go back to learn. And I think that could really help identify gaps in the learning and help you then go back over to reload." (P04, Trainer, NS)*

> *"[…] Yeah, definitely. I find [that] explaining something, helps me to sort of embed that, and sometimes different things will click. You know, you'll learn something and you think you've got that, and then when you're explaining it to somebody else you might then go: Oh! You know, the penny drops, and you think of something else that you hadn't thought of. (P05, Trainee, NS)*

> *"[…] because it can sometimes also highlight gaps in your knowledge. You may think that you have a good grasp of a concept, or a procedure, explanation. And, you then are asked to explain it to someone else and you might realize that your idea of it is not as accurate as you thought. And, you can be challenged on that, any gaps that you have that allows you to re-gather your thoughts and probably explain it better the next time, you understand it better the next time." (P09, Trainee, MS)*

Some participants pointed to the *condition of applicability* of this notion. A Trainee (P06), for example, pointed to the stages in which explaining to others had no enhancing effect on learning. This participant specifically pointed to the *initial stages* of learning despite viewing the *teach-back* method positively. Another participant, a Designer (P07), pointed to a supervised format to avoid potential mistakes while encouraging peers to explain to one another. These participants commented:

> *"Not in the initial stages, no. […] Because I think you're still learning. I think you're very much still learning and […] for me I think, you know, I'd have to sit down and keep playing with it and have a real confidence in myself to then be able to teach it to teach it back. I think there'd be a lot of second guessing in the initial stages." (P06, Trainee, NS)*

> *"[…] that has its drawbacks because you do need to have somebody listening to it because you don't want them to explain the wrong thing. You've still got to have somebody to have an oversight of it. […] And you need to, I suppose, the challenge for people is to know when to do it by the strict rules and when not to do it by the strict rules. And you need to, when you're asking somebody to do it by teaching somebody else, you need to make sure that they know which one applies." (P07, Designer, NS)*

In summary, the findings of this study can be categorised in two sets. The first set involved three themes which reflected the *participants' view* of the suggested techniques. The second set involved three new themes. First, their *interpretation* of cognitive load in their training. Second, their *awareness* of techniques for managing cognitive load. Third, their views on *a potentially new technique* for optimising germane load. These findings are summarised in Table 15 and discussed in the subsequent section.

Table 15. The research findings

| Sets | Findings | Descriptions |
|---|---|---|
| The Themes | Theme one:<br>Preferred Usage | - Captured the participants' *indications of preference*.<br>- Reflected their *preferences* for using the techniques.<br>- Described *which* techniques were preferred. |
| | Theme two:<br>Rationale for Usage | - Captured the participants' *indications of reasons*.<br>- Reflected their *rationale* for using the techniques.<br>- Described *why* techniques were preferred. |
| | Theme three:<br>Perceived Effects | - Captured the participants' *indications of effects*.<br>- Reflected their *perception on the effects* of the techniques.<br>- Described *how* techniques were perceived to exert effect. |
| Other Emergent Findings | Interpretation of cognitive load in EMR system training | - Described the participants' interpretation of cognitive load in training on their EMR system *(a recognised phenomenon)*. |
| | Awareness of techniques for managing cognitive load | - Described the participants' awareness of the techniques known to manage cognitive load *(a notable lack of awareness)*. |
| | A potentially new technique within the CLT framework. | - Described a technique with potential to optimise germane load *(peer-to-peer explanation)*. |

## 4.3. Discussion

This study has explored cognitive load in training on an EMR system and investigated the merits of CLT instructional techniques for this training. In so doing, it has approached actors with different roles in an EMR system training to solicit their views on cognitive load in their training, and the suitability of these techniques for their training. The findings show that (i) the actors have interpreted cognitive load as a *recognised phenomenon* in their training (see RQ1 in Section 1.3); and (ii) they have *positively regarded* the suggested techniques for training on their EMR system (RQ2 in Section 1.3). The findings, notwithstanding the above, also show *a notable lack of awareness* of these techniques amongst the actors and suggests *peer-to-peer explanation* as a potentially new technique for optimising germane load.

### 4.3.1. Cognitive Load as a Recognised Phenomenon

As demonstrated, the actors have interpreted cognitive load as a *recognised phenomenon*. That is, they have acknowledged the existence of cognitive load in their settings. Curiously, not only have they recognised cognitive load *during* their training but also experienced it *before* undergoing training. This interpretation highlights the experience of cognitive load in intensive care environments. An experience that has been attributed either to (i) factors such as *interruptions*, *stress*, and *fatigue* (that are inherent to the nature of work in such environments); or (ii) *information overload* and a *disconnect with instructional materials* (which are inherent to suboptimal learning environments).

Either way, the identified factors are consistent with the literature. The literature contains numerous studies which highlight that interruptions added to cognitive load (Li et al., 2012; Westbrook et al., 2010) or interfered with cognitive functions (Parker & Coiera, 2000). There also exist other studies that point to the fallibility of the human brain under negative emotions such as stress (Eberl et al., 2017; Meguerdichian et al., 2016) and fatigue (Mizuno et al., 2011; Boksem et al., 2005), resulting in failure to complete mental tasks. Furthermore, the literature also contains studies which point to information overload and its overwhelming effect on human cognitive capacity (Kaylor, 2014) as well as the cognitive load imposed by poor instructional design (Chandler & Sweller, 1991; Sweller & Chandler, 1994).

The significance of this finding is trifold. First, it highlights the intensivists' *state of mind*. The intensivists' recurring experience of cognitive load reveals a continuous overload of their cognitive resources, hence an inability to allocate those resources to additional cognitive tasks. One need only visit an intensive care environment to understand the extent to which intensivists are loaded. In fact, they are as cognitively loaded as they are physically and emotionally. Exposure to training, particularly that with poorly designed instructional materials, could exhaust their already loaded cognitive resources and defeat the purpose of training—i.e. the development of the cognitive or psychomotor ability to perform a task (Gallagher et al., 2005). Consequently, a domino effect ensues which could be caused by impaired learning (Young et al., 2014); poor skills acquisition (Gallagher et al., 2005); deteriorated performance (Russ et al., 2018); and unintended harm to patients (Lau et al., 2012).

Second, it highlights the significance of *raising awareness* of techniques to manage cognitive load in an intensive care environment. This study made visible that all actors *lacked awareness* of these techniques. Most notably, all the Designers and Trainers were unaware of these techniques. This could explain, to a significant extent, the Trainees' experience of cognitive load during training. As stated by Ayres and Paas (2012), suboptimal learning environments are created by designers and trainers, and trainees are often unprotected from such environments (p. 830). For that reason, awareness of CLT techniques matters because it could help (i) prevent suboptimal learning; and (ii) minimise the difference in *perceived* and *actual* learning outcomes.

Take Mayer's multimedia principles, for instance, which suggest combining texts and pictures, as opposed to texts alone, for better learning outcomes (Mayer, 2005, cited in Ayres & Paas, 2012). Unaware designers or trainers might adopt this principle while designing or delivering instructions. Unbeknownst to them, however, CLT showed that *the way* texts and pictures are combined could have both positive and negative effects on learning. For example, instructions that *separate* relevant texts and diagrams across time or space render them unintelligible in isolation. The learners experience a split in their attention, which imposes extraneous load and impairs learning (see Section 2.3.4.3). Split-attention and its impairing effect on learning were first recognised by Tarmizi and Sweller (1988) and was replicated by other researchers (Ward & Sweller, 1990; Ayres & Sweller, 2005). In contrast, instructions that *integrate* relevant texts and diagrams enhance learning. This is because they spare learners the cognitive burden of mentally integrating the sources of information that are essential to learning (see Section 2.3.4.4). It also allows them to receive information *multimodally*, which offloads their WM visual and auditory channels and avails their cognitive resources to germane activities which foster better learning. This effect was also reported by Mousavi et al. (1995) and replicated in other studies (e.g., Low & Sweller, 2005).

Third, this finding highlights the Trainees' attempt to enhance their learning experience. Unbeknownst to them, however, they have in effect *self-managed* their own cognitive load and availed their cognitive resources for better learning outcomes. Evidence indicated that arming trainees with techniques to self-manage their cognitive load resulted in enhanced learning. Roodenrys et al. (2012), for instance, demonstrated that (i) not only was it possible to instruct trainees to self-manage cognitive load from Split-attention; but also, (ii) they could transfer this skill to other instructions with a similar issue (p. 878). Although self-managing cognitive load was examined in relation to extraneous load (Roodenrys et al., 2012; Sithole et al., 2017), the findings from this study indicate that it could also be examined in relation to germane load. During the interviews, not only did all five Trainees indicate a strong preference for using Self-explanation but they also experienced better learning outcomes as a result. They pointed to reasons such as 'getting a deeper understanding' (T12-R1-01) or 'talk themselves through' (T12-R1-02) when they explained a concept or procedure to oneself.

These cited reasons are consistent with other studies such as Chi et al. (1989) who found that learners with better success in problem-solving generated many explanations and their "self-explanations [were] guided by accurate monitoring of their own understanding and misunderstanding" (p. 145). Similarly, during the interviews, the participants also indicated a strong preference for using *peer-to-peer explanation* (4 of 5). They pointed to reasons such as 'identifying their knowledge gap' and 'teaching back to oneself' while explaining a concept or procedure to their peers (see Section 4.2.4). This is also consistent with studies such as the one conducted by Noorani et al. (2018), who found that explaining to peers resulted in better learning outcome. Nevertheless, the peer-to-peer explanation is yet to be examined within the CLT framework for its effects on germane load and learning outcome. It could further contribute to instructional techniques for managing germane load, which could be used not only by instructional designers and trainers but more importantly, by trainees to self-manage their cognitive load.

### 4.3.2. Instructional Techniques as Positively Regarded

As also demonstrated, the actors *positively regarded* the techniques. Collectively, the generated themes captured the manner in which the actors viewed the techniques. In other words, not only did these themes capture *which* techniques are preferred, but also *why* they are preferred and *how* they are perceived to exert an effect. Of the twelve suggested techniques, the actors perceived value in most of the 12 techniques suggested for their training. Overall, *nine of twelve techniques* (75%) received preferences from a *minimum of six of nine participants* (approx. 67%).

This translates into *three of six techniques* for reducing the extraneous load (T6, T3, T4) and *all three techniques* for managing the intrinsic load (T7-T9) and optimising germane load (T10-T12), respectively. Furthermore, most *indicated reasons* for using the techniques show consistency with the literature. The same is also true for most *effects perceived* in using the techniques. This has significance because (i) it shows an alignment in the actors' rationale with those who developed and empirically tested these techniques; and (ii) it provides a plausible explanation *why* and *how* these techniques could have merits for their EMR system training. To illustrate, the indicated reasons and perceived effects of the most preferred techniques to manage each category of cognitive load are discussed in the subsequent pages.

#### *4.3.2.1. Techniques for Reducing Extraneous Load*

The most cited reasons and perceived effects associated with using the top three techniques in this category (T6, T3, T4) are consistent with the literature. For example, the most cited reason for Redundancy (T6) highlighted that repeating information sufficiently could 'help reinforce learning' (T6-R1-01) provided that it 'avoids repetitiveness' (T6-E1a-02). Many studies have found that repetitive or redundant information was an obstacle to schema acquisition and learning (e.g., Chandler & Sweller, 1991; Sweller & Chandler, 1994). This is because redundant information, particularly that which is self-contained and intelligible on its own, requires trainees to allocate their cognitive resources to *similar information* (Liu et al., 2012) rather than *complementary information* (Mayer et al., 2001). Consequently, they experienced an extraneous load (Sweller, 1993) caused by unnecessary processing of identical yet superfluous information (van Merriënboer & Sweller, 2010). Likewise, the reasons and effects indicated for Split-attention (T3) and Modality (T4) also show consistency with the literature. For instance, the most cited reason for Split-attention (T3) pointed to 'help seeing the link' (T3-R1-01) when multiple sources of information—which are essential to learning and unintelligible in isolation—are *integrated* together. As a result, the effects perceived on learning highlighted 'getting the full picture' (T3-E1a-02) and 'avoiding unnecessary processing' (T3-E1a-01) of information. Several studies have reported increased extraneous load due to *mental integration* (Tarmizi & Sweller, 1988), as opposed to *physical integration* (Chandler & Sweller, 1992), of multiple sources of information. They commonly attribute this to the diversion of WM resources from forming schema to dealing with extraneous load (Sweller et al., 2011a).

Like the top three techniques for reducing extraneous load, the indicated reasons and the perceived effects for the bottom three techniques in this category (T1, T2, T5) also show consistency with the literature. Worked Example (T1) was the least preferred amongst all techniques (3 of 9 participants). This was unexpected considering its significance to CLT and other instructional techniques (see Section 4.1). Remarkably, almost all participants who have indicated no preference for this technique (5 of 6), indicated 'getting involved and explore' as their reason (T1-R2-01, T1-R3-01, T1-R4-01). In particular, two Trainees (P03, P05) pointed to the unsuitability of this technique for 'active learning' (T1-R5-03). Other researchers also raised concerns over non-active or *passive learning* in studying worked examples. For example, Sweller and Cooper (1985) were among the first who raised concerns that learners would not process worked examples in sufficient depth. Chi et al. (1989) also argued that learners might only study worked examples in sufficient depth when they faced difficulty solving other forms of problems.

Nevertheless, three participants preferred using Problem Completion (T2), which was developed to ensure active learning while studying worked examples (van Merriënboer & Krammer, 1987).

Recalling from Chapter Two (Section 2.3.4.2), this technique provides a step-by-step solution to a problem, but in so doing, it provides partially filled examples for learners to complete. In other words, this technique is "an alternative to the standard format for worked examples" (Clark et al., 2011, p. 106). In particular, these participants pointed to 'improving attentiveness' (T2-R1-02) as the reason for preferring this technique. They perceived 'being more engaged' (T2-E1a-02) as a positive effect on their learning. These indicated reasons and effects also show consistency with the literature. According to Sweller (1999), adding a problem-solving element, such as a partially completed example, could ensure sufficient depth of study. This is because learners must carefully study and understand these problems to be able to complete the solution correctly (Sweller et al., 2019).

#### *4.3.2.2. Techniques for Managing Intrinsic Load*

Similarly, the techniques for managing intrinsic load (T7, T8, T9) generated several reasons and effects. The cited reasons and perceived effects associated with using these techniques also show consistency with the literature. For instance, the most cited reasons for Simple-to-complex (T9), when instructions first present the simpler version of a task, and then the more complex version of that task, pointed to 'make understanding easier' (T9-R1-02) and 'allow to build-up' (T9-R1-01). The effect most perceived on learning has pointed to 'enabling progression' (T9-E1a-01). Several studies have highlighted *sequencing* a learning task and its effect on intrinsic load (e.g., van Merriënboer et al., 2003; Paas & van Gog, 2009). They particularly emphasised that a *progressive* presentation of information helped assimilation of complex information (Pollock et al., 2002). In other words, by not presenting the full information at once, the intrinsic load can be reduced, resulting in better learning. One might argue, however, that this approach could negatively affect understanding as information is not presented in full, and the interaction between the information elements is not fully learned (cf. Hoogerheide & Paas, 2012, p. 893). However, as stressed by van Merriënboer and Sweller (2010), this deficiency is compensated by presenting the more complex version of the same task (p. 91) at the later stage when the learners had gained the necessary schema and were able to build the new information upon it. The same was also found to be true for Low- to high-physical fidelity (T8) in the learning environment (van Merriënboer & Kirschner, 2017) and Isolated Elements (T7) in instructional methods (Pollock et al., 2002).[3]

### *4.3.2.3. Techniques for Optimising Germane Load*

In a similar manner, the techniques for optimising germane load (T10, T11, T12) generated several reasons and effects. The indicated reasons and perceived effects associated with using these techniques are also consistent with the literature. For instance, the most cited reasons for Self-explanation (T12) pointed to 'talk themselves through' (T12-R1-02) and 'get a deeper understanding' (T12-R1-01) when explaining a concept or procedure to oneself. These reasons have been indicated by almost all actors (8 of 9). The effects of using this technique have been perceived by all actors to be 'stimulating the brain' (T12-E1a-02) and 'identifying one's knowledge gap' (T12-E1a-01). Several studies have showed that self-explaining a concept is beneficial to learning because the learner can elaborate on its applicability (e.g., Chi et al., 1989) and think about the underlying rationale behind that concept (Roy & Chi, 2005). Others argued that self-explaining helped organise learners' cognitive schema, and showed their missing information (Eysink et al., 2009). This effect had been recognised earlier by Renkl et al. (1998) who argued that learners, through Self-explanation, could have less illusion of comprehension because they could *diagnose the failure* in their comprehension, what Roy and Chi (2005) referred to as "monitoring and repairing faulty knowledge" (p. 272). The same was also true for the next most preferred techniques in this category, Imagination (T11). This can be explained, to some extent, by the emphasis of these two techniques on 'mental practice' (see Sections 2.3.6.2 and 2.3.6.3). As described by Beasley (1979), mental practice is one's introspective or covert rehearsal for performing a task, and evidence has indicated that mentally rehearsing a learning task is more beneficial (Ericsson & Charness, 1994) than only studying a task. The indicated reason and perceived effect associated with these techniques also pointed to 'allowing to think it through' (T11-R1-01) and 'enabling a mental rehearsal' (T11-E1a-01).

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[3] See the indicated reasons and effects for Isolated Elements (T7) including 'make easier to understanding (T7-R1-02) and 'by enabling progression' (T7-E1a-01), respectively. Also see in the same order, the indicated reasons and effect for Low- to high-physical fidelity (T8) including 'allows to build-up' (T8-R1-01) and 'by enabling progression' (T8-E1a-01).

In view of the above, one important point to consider is the relevance of CLT and its instructional techniques for managing different categories of cognitive load, not only to the medical domain (van Merriënboer & Sweller, 2010; Young et al., 2014) but also to the broader areas of information systems. Several studies have recognised the merits of this theory and informed their instructional interventions to enhance learning in the IS domain. Examples include query formulation with SQL (Vijayasarathy & Casterella, 2016); interruptions to interface design in social commerce (Zhang et al., 2019); computer-mediated learning (Eryilmaz et al., 2013) and communication (Sobotta, 2016); programming (Pirolli & Recker, 1994); and multimedia learning (Wylie & Chi, 2014).

### 4.4. Chapter Summary

This chapter has reported the findings of this study. In so doing, it first provided a brief overview of the analytical process from the earlier chapter (Section 4.1) and presented the findings from this process (Section 4.2). Two categories represented these findings: the *themes* and *other emergent findings*. The themes comprised (i) *Preferred Usage*; (ii) *Rationale for Usage*; and (iii) *Perceived Effects*. In the same order, each theme described *which* techniques were preferred; *why* they were preferred; and *how* they were perceived to exert effects (Sections 4.2.1 – 4.2.3). Apart from these themes, other emergent findings highlighted (i) *interpretation of cognitive load*; (ii) *awareness of instructional techniques*; and (iii) *peer-to-peer explanation* as a potentially new technique for CLT in optimising germane load (Section 4.2.4). Relevant data extracts provided qualitative evidence for both categories of findings.

The chapter continued by discussing the findings (Section 4.3). In doing so, it first reorganised the findings and showed how they related to the research questions. It then interpreted these findings and posited them in the broader literature. The discussion highlighted that the participant (i) interpreted cognitive load as a *recognised phenomenon* both *before* and *during* their training (Section 4.3.1); and (ii) they *positively regarded* the techniques for their training (Section 4.3.2). Overall, 67% of the participants (6 of 9) preferred 75% of the techniques (9 of 12). Their preferences, along with their rationale and perceived effects, were discussed for each category of cognitive load.

# CHAPTER FIVE

# CONCLUSION

This chapter concludes this study. The chapter first recapitulates the study and continues by answering the research questions based on its findings. Also, it discusses the theoretical and practical implications and explains the contributions of this study to the body of knowledge. The chapter also discusses the strengths and limitations of the study and concludes by sketching directions for future research.

## 5.1. Review of the Study

Cognitive load as a socio-technical variable contributes to HIT problems involving human factors. Problems involving human factors, however, have been found to be *significantly more likely* to harm patients compared to those involving technical factors. Nevertheless, for EMR systems, a widespread form of HIT, cognitive load has only been examined in areas involving the *design* and *use* of these systems. Consequently, other areas such as *training*, another socio-technical variable contributing to problems involving human factors, has remained under-researched (see Chapter One). Evidence, however, strongly points to the *impairing effect* of cognitive load on learning during training. In response, cognitive load researchers have devised and tested several instructional techniques to manage cognitive load in training. Nonetheless, neither *cognitive load* nor *instructional techniques*, known to manage cognitive load, have been hitherto examined in training on EMR systems. This study explored cognitive load in training on an EMR system and investigated the merits of instructional techniques for managing cognitive load in such training. In so doing, the study sought to address the following research questions:

*Research Question 1:*
*How is cognitive load interpreted in EMR systems training?*

*Research Question 2:*
*How are instructional design techniques, known to manage cognitive load, regarded by different actors in EMR systems training?*

To answer these questions, the study adopted an interpretive case study. It utilised semi-structured interviews and reflective thematic analysis for collection and analysis of the data. It subscribed to Cognitive Load Theory (see Chapter Two) and interviewed actors with different roles in an EMR system training in a Neonatal Intensive Care Unit at a public hospital in Melbourne, Australia. (see Chapter Three). These actors were *Designers* of instructional materials; *Trainers* delivering these materials; and *Trainees* learning through the same materials. All actors were also serving as either medical or nursing staff at the same neonatal intensive care unit. The thematic analysis of the data from the interviews generated *three salient themes* and *three emergent findings* (see Chapter Four), which provided clear answers to the research questions.

## 5.2. Answers to Research Questions

In answer to the first research question, the findings showed that the actors interpreted cognitive load as a *recognised phenomenon*, not only in their training but also in their workplace. This finding highlighted two points; first, the *existence* of cognitive load in training on an EMR system and second, the *state of mind* of intensivists and their experiences of cognitive load. These points provided new insights into the problems involving human factors in an EMR system. The intensivists' recurring exposure to cognitive load, both *before* and *during* training, translated into an inability to allocate their cognitive resources to additional cognitive tasks such as learning how to use the system. As a result, they could experience a continuous state of impaired learning, which, in turn, could result in poor skills acquisition and deteriorated performance and ultimately in unintended harm to patients.

In answer to the second research question, the findings indicated that the actors *positively regarded* the suggested techniques for training on their EMR system. That is, a minimum of *six of nine participants* (approx. 67%) preferred using *nine of twelve techniques* (75%). In terms of actors, (i) Trainees preferred on average 11 techniques; (ii) Designers preferred 8.5; and (iii) Trainees preferred 8.2 of the suggested twelve techniques. In term of techniques, these comprised (i) *three of six* techniques for reducing extraneous load; (ii) *all three* techniques for managing intrinsic load; and (iii) *all three* techniques for optimising germane load. Their indicated reasons and perceived effects were also consistent with the literature, which provided further support for their preferences. This finding suggested that the actors considered a sizable number of techniques to have merits for their EMR system training.

## 5.3. Practical and Theoretical Implications

The findings presented above have implications for both practical and theoretical domains. These findings confirm the *existence* of cognitive load in, and the *merits* of instructional techniques for, *an* EMR system training. Nevertheless, in the context of this study (i.e. intensive care), the findings indicate that the intensivists experience cognitive load *before* and *during* training.

In the practical domain, these findings highlight the intensivists' *state of mind* and provide qualitative support to show that not only can the cognitive load be induced by training (e.g., by poor instructional design) but also can be generated by environmental factors (e.g., stress and fatigue). This should be taken into consideration by designers and trainers when designing or delivering instructional materials for training in these contexts. In these contexts, the trainees (i.e. intensivists) are exposed to a recurring experience of cognitive load from the environmental factors. As a result, they may be unable to allocate their already loaded, or in some cases almost exhausted, cognitive resources to additional cognitive tasks such as learning how to use a new system. This could be particularly pronounced for training on a new EMR system because its implementation is often extremely disruptive (Jha et al., 2008). In such cases, informing training with instructional techniques that are specifically designed to manage cognitive load, could transform training on a new system *from aggravating to alleviating* the experience of cognitive load. Awareness of the suggested instructional techniques could help designers to design the training materials to help manage cognitive load. For example, by using the techniques for managing intrinsic load, the designers can influence the level of element interactivity of the materials and titrate the presentation of those elements to trainees—e.g., by sequential information presentation (Section 2.3.5.1). Similarly, by using the techniques for optimising germane load, the trainers can provide prompts to stimulate the trainees' germane activities—e.g., by mentally rehearsing a procedure (Section 2.3.6.2). In a similar manner, using the techniques to *self-manage* cognitive load, the trainees can manage their *own* extraneous and germane load during the training—e.g., by physically integrating information sources (Section 2.3.4.3) and by self-explaining a procedure (Section 2.3.6.3).

In the theoretical domain, the findings further confirm the relevance of CLT to the medical domain. CLT has relevance to the medical domain because learning tasks in this domain requires the integration of multiple sources of information, which can cognitively load medical professionals, impact their learning, and subsequently affect their performance. Extending on the relevance of this theory to inform medical education and curriculum design in this domain (see van Merriënboer & Sweller, 2010; Young et al., 2014), the findings of this study suggest that CLT can also inform a new subset in the medical domain; that is, medical systems and instructional designs for their training. One may argue that education differs from training and they are used, often by mistake, interchangeably. I concur, but I also suggest that education *as the acquisition of knowledge* and training *as the acquisition of skills* (see Gallagher et al., 2005) are related and even complementary in this domain. This is because effective treatment of patients, particularly in intensive care environments, is a function of *sound medical knowledge* acquired through education as well as *superior system skills* acquired through training. Both areas can equally benefit from CLT because they have a focal point in common—learning. The findings of this study motivate a further question about the relevance of CLT to medical system training other than EMR systems.

## 5.4. Contributions

As a case study with an interpretivist stance, the contributions of this study shall be evaluated in terms of *generalisability*. Walsham (1995) extended on Yin (1989), who suggested that a single case study is generalisable to the theoretical proposition, and proposed *four types* of generalisability from interpretive case studies: (i) development of concept; (ii) generation of theory; (iii) drawing of specific implications; and (iv) contribution to rich insights (p. 79). This study makes contributions in terms of the last item in this categorisation, namely *contribution to rich insight*. In this regard, this study highlights three noteworthy points, which contribute to an in-depth understanding of cognitive load in training on an EMR system in intensive care.

The first point involves confirming the *existence* of cognitive load both *before* and *during* training. The study provides qualitative evidence that shows, in an intensive care environment, environmental factors such as stress and fatigue can induce cognitive load. The evidence also shows that a suboptimal learning environment caused by poor instructional design can further increase cognitive load. This point, in essence, highlights the intensivists' *state of mind* when undertaking training in such an environment. This state of mind, however, may not be immediately visible to instructional designers or trainers. The evidence from this study points to the intensivists' overloaded cognitive resources, which can be further strained by poorly designed or delivered training. As a result, unable to allocate their cognitive resources to additional cognitive tasks, the intensivists may not learn how to use a new system. This inability can be particularly pronounced when an intensive care unit implements a new EMR system, which can be an extremely disruptive experience for both the unit and its staff.

The second point highlights the intensivists' tendency to *self-manage* their cognitive load. The evidence from this study indicates that the intensivists either preferred using techniques such as Imagination and Self-explanation to help optimise their germane load; or used techniques such as *peer-to-peer explanations* to enhance their germane processing. Cognitive load researchers have examined self-management of extraneous cognitive load. This study, however, could serve as a basis for future inquiries on self-managing the *germane* cognitive load. Such inquiries could be particularly interesting in terms of *the peer-to-peer explanation*, which could be a new instructional technique for CLT.

The last point involves the *interplay* between socio-technical variables such as *cognitive load* and *training* and their reciprocal influence on problems involving human factors. As stated earlier, socio-technical variables, such as cognitive load and training, have been viewed as contributing to HIT problems that involve human factors. This study further confirms the reciprocal influence of cognitive load and training in the EMR system at the Participating Organisation. This study can serve as the basis for further inquiries into how such an interplay can contribute to other EMR systems.

## 5.5. Strengths and Limitations

As an interpretive case study, the strengths and limitations of this study should be evaluated with criteria that accurately reflect the underlying assumptions of the interpretivist paradigm. A well-regarded set of criteria was suggested by Guba and Lincoln (1989). These criteria comprise (i) *credibility*; (ii) *transferability*; (iii) *dependability*; and (iv) *confirmability*. This section evaluates the strengths and limitations of this study against these criteria to establish trustworthiness. In particular, it focuses on the study's design (Section 3.2); conduct (Section 3.3); and findings (Sections 4.2. and 4.3).

*Credibility* focuses on truth value. It refers to the manner in which the researcher presents the context, the participants, and their experience in that context. According to Guba and Lincoln (1989), the extent to which a study is credible depends upon a *reasonable match* between the representations made by the participants and the researcher. In other words, a study is credible "when it presents such faithful descriptions or interpretations of human experience that the people having that experience would immediately recognise it from those descriptions or interpretations as their own" (Sandelowski, 1986, p. 30).

This study explored (i) cognitive load in training on an EMR system; and (ii) the merits of instructional techniques for this training. The study subscribed to CLT as a theoretical lens, which evolved around cognitive load. The design of the study allowed for a focus on individuals' experiences and their perception of cognitive load in training within their own settings. The instrument used for data collection was specifically designed to solicit views on cognitive load and techniques for managing it from multiple actors with different roles in training on their EMR system. This allowed triangulation though multiple data sources. Similarly, the framework that guided the thematic analysis of the data was underpinned by a qualitative philosophy, which emphasises meanings as contextual and realities as multiple (Braun & Clarke, 2013). It also emphasised the coherent and *grounded* interpretation of the data and the role of the researcher as a *storyteller* (Braun et al., 2018, p. 6). Together, these allowed for a reasonable match between the participants' experience and what the author reported on their experience through a well-grounded theoretical lens. That is, they experienced cognitive load *before* and *during* training due to *environmental* (e.g., fatigues and stress) or *instructional* factors (e.g., poor design or delivery). Other intensivists who are exposed to these factors may recognise the same experience of cognitive load reported in this study.

*Transferability* focuses on applicability. It refers to the extent to which the findings are applicable to other populations or settings. In this study, the number of participants was relatively small (nine). Although this number was reasonably representative for each actor, it limited the transferability of the findings. During the data collection process, the Participating Organisation was adopting a new EMR system, and most staff were undergoing training in that system. Consequently, access to Trainees was very limited. Access to Designers and Trainers was relatively easier. This is because the design and delivery of training for the new system were outsourced. As a result, all Designers (2 of 2) and Trainers (2 of 2) were interviewed. Having participants in different roles allowed triangulation of the data from multiple perspectives.

In this light, it is reasonable to conclude that the findings can be generalised to other EMR systems or other actors involved in training on those systems. Confidence in transferability of the findings is likely to increase if the actors involved a larger number of participants (e.g., more designers, trainers, or trainees for other EMR systems). Similarly, it is also likely to increase if the number of case studies involved more EMR systems in other intensive care units (e.g., at different healthcare organisations). This could result in a greater number of participants, and transferability of their views to other settings. However, it was beyond the scope of this study to focus on other cases for EMR systems in different settings. This represents potentials for future studies, which are discussed in the next section.

*Dependability* focuses on consistency. It depends on the extent of auditability of the processes involved or what Sandelowski (1986) referred to as trackability of the researcher's "decision trail" by other researchers (p. 33). In other words, dependability requires transparency in the research processes (Guba & Lincoln, 1989). The study described each process involved in its design and conduct. In particular, it detailed the decisions and steps in the thematic analysis of the data before and during the analytic process (see Sections 3.3.2.2 and 3.3.2.3). Furthermore, it identified each data item with a unique Data ID and associated each with the relevant data extracts. As a result, the data is available to other researchers to review the coding schemes and how the associated data extracts support the meanings and interpretations (see Appendix H).

*Confirmability* focuses on neutrality. Neutrality, as defined by Sandelowski (1986) is the freedom from bias (p. 33). Nevertheless, in the qualitative sense, neutrality refers to the *findings*—not the researcher's subjective or objective stance (p. 34). In other words, the researcher provides corroborating evidence that the findings are grounded in the data. In this study, conformability was ensured by (i) triangulation; (ii) sceptical peer review; and (iii) reflective journal keeping (see Devers, 1999, p. 1171). Firstly, the study used *multiple data sources*. It solicited the views of multiple actors with different roles in an EMR system training. As a result, the author was able to triangulate their interpretations and corroborate their views on cognitive load and techniques to manage it. Secondly, the study used a *sceptical peer reviewer*. The reviewer critically questioned the meanings and interpretations of the data. As a result, the author was able to have an *external check* despite the lack of multiple investigators for triangulation. Lastly, the author kept a *reflective journal* of his personal biases that could influence the study or its outcomes. Therefore, the author was able to provide an *audit trail* for other researchers to trace his decisions during data analysis.

In view of the above, it is reasonable to state that the study provides *confirmable* and *dependable* findings.

This, in turn, helps establish *credibility* for the study and discuss its *transferability* within the confines of an interpretive case study (see Erlandson et al., 1993, cited in Petty et al., 2012).

## 5.6. Future Research

In line with its contributions, this study motivates three areas for future research. The first area involves reconfirming the *existence* of cognitive load before and during training in other EMR systems in intensive care. Not only would such an outcome further reinforce this study's findings but also increase confidence in its transferability to training on other EMR systems. Highlighting the intensivists' *state of mind* would draw closer attention to (i) their inability to allocate cognitive resources to additional cognitive tasks; and (ii) the resultant failure of training in transferring skills necessary to use these systems competently. This can shed more light on socio-technical variables, such as cognitive load and training, contributing to problems involving human factors particularly for EMR systems as a prevalent form of HIT (see Magrabi et al., 2015). Similarly, it can also enrich the discussion on the *interplay* of such socio-technical variables and their reciprocal influence on those problems for EMR systems.

The second area involves the *merits* of instructional techniques for *other EMR systems*. This outcome can also build confidence in the transferability of this study's findings to other EMR systems. In this regard, the suitability of CLT and its techniques for instructional interventions for training on other EMR systems can be reconfirmed. This can encourage further enquiries into the *application* of these techniques to the design of the instructional materials for EMR systems as well as the *measurement* of the resultant cognitive load on intensivists. CLT provides several methods for measuring cognitive load using both objective and subjective methods. The objective methods involve physiological measures such as pupillary response (van Gerven et al., 2004), eye-tracking (van Gog & Jarodzka, 2013), and brain electrical activity (Antonenko et al., 2010). The subjective methods, in contrast, use a multi-point scale to *self-rate* the individual's perception of cognitive load. These methods are based on the premise that people can assess their mental effort as an index of cognitive load. In comparison with the other methods, the subjective methods seem to be more practical (Morrison et al., 2014), less intrusive (Paas & van Merriënboer, 1994), more sensitive (Sweller et al., 2011b), and consistent in matching performance data predicted by CLT (Moreno, 2004). The recent developments in this area allow the measurement of different categories of cognitive load (Leppink et al., 2013) as opposed to its overall level (Paas, 1992).

The last area involves future investigations into *peer-to-peer explanation* as a new technique in CLT. As stated earlier, the finding from this study points to the intensivists' tendency to *self-manage* their cognitive load. In their responses, it is evident that they prefer to explain a concept or procedure either to *themselves* or their *peers* to enhance their learning experience. To this date, cognitive load researchers have examined self-managing cognitive load in relation to its *extraneous* category only (Roodenrys et al., 2012; Sithole et al., 2017). The findings from this study, however, encourage further research in self-managing the *germane* category of cognitive load. It would be interesting to see how teaching the intensivists to use techniques to self-manage their cognitive load could help their germane processing, and hence improve their learning outcomes. Of particular interest is further research into a new technique within the CLT framework for this purpose—namely *peer-to-peer explanation*.

### 5.7. Concluding Remarks

The study has contributed to the body of knowledge focusing on socio-technical variables, such as cognitive load and training, and how they could contribute to problems involving human factors in EMR system as a prevalent form of HIT. The study has demonstrated that cognitive load *exits* before and during training on this system in intensive care, which highlights the intensivists' *state of mind* when undertaking training. The study has also demonstrated that instructional techniques *have merit* for managing cognitive load in training on this system, which highlights the significance of *awareness* of the instructional techniques for Designers, Trainers, and Trainees involved in training on this system. By doing so, the study has further confirmed the relevance of CLT to the medical domain; not only medical education but also medical system training.

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# APPENDICES

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## Appendix A: Ethics Approval (Participating Organisation)

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[redacted]

27 November 2018

[redacted]

[redacted]

Dear Researcher,

**Study title: Health Information Technology and Cognitive Load**

[redacted]

The [redacted] Human Research Ethics Committee Low Risk Panel has reviewed the above application. In addition, the Low Risk Panel is satisfied that the responses to our correspondence of 2 October 2018 have been sufficiently addressed.

The Low Risk Panel approved the above application on the basis of the information provided in the application form, protocol and supporting documentation.

This reviewing Low Risk Panel is a Sub-committee of the Human Research Ethics Committee which is accredited by the Consultative Council for Clinical Trial Research under the single ethical review system.

**Approval**

The Low Risk Human Research Ethics approval is from 27 November 2018.

Approval is given in accordance with the research conforming to the *National Health and Medical Research Council Act 1992* and the *National Statement on Ethical Conduct in Human Research (2007)*. The HREC has ethically approved this research according to the Memorandum of Understanding between the Consultative Council and the participating organisations conducting the research.

Approval is given for this research project to be conducted at the following sites and campuses:

- [redacted]
- Monash University

You must comply with the following conditions:

The Chief Principal Investigator is required to notify the Manager, Human Research Ethics Committees, [redacted] of:

1. Any change in protocol and the reason for that change together with an indication of ethical implications (if any)
2. Suspected Unexpected Serious Adverse Reactions (SUSARs) involving a [redacted] participant or a participant at site that Monash Health has provided HREC Review.
3. Serious Adverse Events (SAEs) that occur with a [redacted] participant or with a participant from a site that [redacted] has provided HREC review that are

[redacted]

considered by the Investigator as being definitely related, probably related, possibly related and unknown.

4. Any unforeseen events that might affect continued ethical acceptability of the project.
5. Any expiry of the insurance coverage provided in respect of sponsored trials.
6. Discontinuation of the project before the expected date of completion, giving reasons.
7. Any change in personnel involved in the research project including any study member resigning from [redacted] &/or the study team.

At the conclusion of the project or every twelve months if the project continues, the Principal Investigator is required to complete and forward an annual progress report to the Committee.

Reminders to submit annual progress report forms will be forwarded to the researcher.

The Coordinating Principal Investigator is responsible for notifying Principal Investigators. The Coordinating Principal Investigator and Principal Investigators should forward a copy of this letter to their site's Research Governance Officer.

**Approved documents**

Documents reviewed and approved are as follows:

| *Document* | *Version* | *Date* |
|---|---|---|
| Human Research Ethics Application Form | | 19/9/2018 |
| Victorian Specific Module | | 19/9/2018 |
| Protocol | 1.4 | 19/10/2018 |
| Explanatory Statement | 3 | 25/10/2018 |
| Consent Form | 3 | 25/10/2018 |
| Study Pamphlet | 2 | 25/10/2018 |
| Semi-Structured Interview instrument | 2 | 15/10/2018 |

**Site-Specific Assessment (SSA)**

SSA authorisation is required at all sites participating in the study. SSA must be authorised at a site before the research project can commence.

The completed Site-Specific Assessment Form and a copy of this ethics approval letter must be submitted to the Research Governance Officer for authorisation by the Chief Executive or delegate. This applies to each site participating in the research.

If you should have any queries about your project please contact [redacted] or [redacted] by email [redacted]

The Low Risk Panel wishes you and your colleagues every success in your research.

Yours sincerely

[redacted]

Manager, Human Research Ethics Committee

**Checklist: Post-ethics approval requirements that must be met before a research project can commence at a study site.**

**Please ensure that as a PI (including the CPI) the following are completed at each study site.**

| **Requirements** | **Yes/No/NA** |
|---|---|
| **Ethics approval notification**<br>The PI must send a copy to the RGO at that study site. | Yes |
| **HREC Review Only Indemnity**<br>The PI must forward a copy of the signed HREC Review Only Indemnity to the RGO at that study site. | N/A |
| **SSA authorisation notification**<br>The PI must forward the SSA form and attached documents (e.g. CTRA) to the RGO so the authority approving the conduct of the trial, at that site, can complete and sign. | Yes |
| **Other Commonwealth statutory requirements**<br>Ensure compliance with the following e.g. Office of the Gene Technology Regulator, NHMRC Licensing Committee, NHMRC Cellular Therapies Advisory Committee. | N/A |

## Appendix B: Confirmation of Registration (MUHREC)

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**Monash University Human Research Ethics Committee**

**Confirmation of Registration**

| | |
|---|---|
| **Project Number:** | 18448 |
| **Project Title:** | Health Information Technology and Cognitive Load |
| **Chief Investigator:** | Professor Frada Burstein |
| **Registration Date:** | 05/02/2019 |
| **Expiry Date:** | 05/02/2024 |

**Terms:**

1. Registration is valid whilst you hold a position at Monash University, and approval at the primary HREC is current.
2. This notification does not constitute HREC approval. It is the responsibility of the Chief Investigator to ensure that approval from the primary HREC continues for the duration of the research.
3. End of project: You should notify MUHREC at the conclusion of the project or if the project is discontinued before the expected date of completion.
4. Retention and storage of data: The Chief Investigator is responsible for the storage and retention of the original data pertaining to this project in accordance with the *Australian Code for the Responsible Conduct of Research*.

Kind Regards

Professor Nip Thomson

Chair, MUHREC

CC: Assoc Professor Chivonne Algeo, Mr Sarang Hashemi

## Appendix C: Explanatory Statement

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MONASH University

## EXPLANATORY STATEMENT

**Project: Health Information Technology and Cognitive Load**

**Sarang Hashemi**
School of Information Technology
Phone: 0413 729 123
email: sarang.hashemi@monash.edu

[redacted]

**Prof. Frada Burstein**
School of Information Technology
Phone: 03 9903 2011
email: frada.burstein@monash.edu

[redacted]

**A/Professor Chivonne Algeo**
School of Information Technology
Phone: 03 9903 1082
email: chivonne.algeo@monash.edu

You are invited to take part in this study. Please read this Explanatory Statement in full before deciding whether or not to participate in this research. If you would like further information regarding any aspect of this project, you are encouraged to contact Mr Sarang Hashemi via the phone number or email address listed above.

This project will be carried out according to the *National Statement on Ethical Conduct in Human Research (2007)* produced by the National Health and Medical Research Council of Australia. This statement has been developed to protect the interests of people who agree to participate in human research studies.

The ethical aspects of this research project have been approved by the Human Research Ethics Committees of [redacted]

**What does the research involve?**
The aim of this study is to explore the cognitive load that is imposed by the training and instructional materials of Electronic Medical Record (EMR) system on its prospective users (e.g., the medical and nursing staff) within the Neonatal Intensive Care Unit (NICU). The study is designed to understand the impact of instructional materials of the EMR system and disruption caused by transitioning to the system from the lens of cognitive load and its effects on learning and performance of the medical and nursing staff.

**Why were you chosen for this research?**
The Chief Investigator of this research project would have recommended you to us.

**What does the participation involve?**
Participation in this study involves an interview session. In this session, the researcher will present you with short survey to fill and ask you a set of questions to record your answers for detailed analysis. The interview session is expected to complete within 30 to 45 minutes and your answers remains confidential.

**Consenting to participate in the project and withdrawing from the research**
Being in this study is voluntary and you are under no obligation to consent to participation. However, if you do consent to participate, you may withdraw from further participation at any stage but you will not be able to withdraw data that has been collected.

**Possible benefits and risks to participants**
There will be no direct benefits for participants. However, findings from this research will provide a better understanding of the effects of instructional materials on the level of cognitive load that is experienced by the medical and nursing staff during their training for an EMR system and subsequently their learning and performance outcomes.

We believe that there will be no stress, inconvenience or discomfort to any of the participants.

**Confidentiality**
All information collected in this study will be de-identified. Collected data will be used for scientific publications while maintaining the anonymity of the data sources. The information collected on the consent form will not be published, or released in any way.

**Storage of data**
The data will be stored in accordance with Monash University Regulations, kept in a secured Monash shared drive for the retention time of seven years. A report of study or data may be submitted for publication, but individual participants will not be identifiable in such a report. Any data provided or acquired by the participant will remain confidential. Any data used for research publications will be de-identified by labelling each participant as P1, P2, P3 and so on. The data will only be available to the research team.

**Use of data for other purposes**
The data collected may be used for other purposes in a completely de-identified form, subject to the approval of the Chief Investigator, where ethics approval has been granted.

**Results**
Participants may opt to be informed of the research findings by contacting us by email:

Frada Burstein: frada.burstein@monash.edu

**Complaints**
Should you have any concerns or complaints about the conduct of the project, you are welcome to contact [redacted]

Thank you,

**Sarang Hashemi, Prof. Frada Burstien, A/Prof. Chivonne Algeo, [redacted]**

## Appendix D: Consent Form

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MONASH University

## CONSENT FORM

**Project:** 'Health Information Technology and Cognitive Load'

**Chief Investigators:** Prof. Frada Burstein, A/Prof. Chivonne Algeo, [redacted]

**Investigator:** Seyed Sarang Hashemi

**Note**: this consent form will be retained in the chief investigator for their records.

I have been asked to take part in the Monash University research project specified above. I have read and understood the Explanatory Statement and I hereby consent to participate in this project.

| **I consent to the following:** | Yes | No |
|---|---|---|
| I agree to be interviewed by the researcher and provide some demonstration if needed | ☐ | ☐ |
| I agree to allow the interview to be audio-recorded | ☐ | ☐ |
| I agree the data that I provide during this research may be used by the researchers in future research projects | ☐ | ☐ |

**And I understand:**

- that my participation is voluntary, that I can choose not to participate in part or all of the project
- that I can withdraw up to the end of the interview without being penalised or disadvantaged in any way
- that any data that the researcher obtains from the interview for use in reports or published findings will not, under any circumstances, contain names or identifying characteristics
- that any information I provide is confidential
- all data related to the interview will be kept in secure storage. I also understand that the data will be destroyed after 7 year period unless I consent to it being used in future research.

**Name of Participant** ______________________________

**Participant Signature** ______________________________ **Date** ______________

# Appendix E: Study Pamphlet

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MONASH University

[redacted]

Image credit to http://ww.rizoomes.nl/8866-2/

# A Research Study about: Health Information Technology and Cognitive Load

## What is the study about?

Our team from the Faculty of Information Technology at Monash University is studying how Electronic Medical Record (EMR) systems affect cognitive load of its users. This research study is for medical and nursing staff at Monash Newborn's neonatal intensive care units who use the NICU's EMR system. Participation in this research is voluntary.

This project has been approved by [redacted] Human Research Ethics Committee.

## Who can participate?

This study may be a good fit for you if:

- You are using EMR system in NICU settings, or
- You received training to use EMR system, or
- You aspire to improve the instructional and training materials for EMR systems.

## What is involved?

This study involves a session comprising of a short survey and an interview. The session is expected to take approximately 30-45 minutes to complete. The session will take place in double staff time between March 1 to 31, 2019.

Participants who take part will receive refreshments from [redacted] as a gesture to thank them for their time.

## Location of Research:

This research will take place at [redacted]

## Contact Information:

To take part in this research study or for more information, please kindly contact Sarang Hashemi via the following email address: sarang.hashemi@monash.edu

## Principle Investigator:

Sarang Hashemi
Faculty of Information Technology
Monash University
E: sarang.hashemi@monash.edu
[redacted]



[redacted]

## Appendix F: Interview Protocol

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DEFINITIONS OF TERMS
(ALL PARTICIPANTS)

**Cognitive Load:**
Cognitive load can be defined as the load imposed on an individual's working memory by a particular task.

**Working Memory:**
Working memory processes the information that it receives from the individual's sensory system (e.g., visual information from the eyes or auditory information from the ears).

**Intrinsic Cognitive Load:**
Intrinsic cognitive load refers to the load that is imposed on working memory, which is inherent to the task at hand.

**Extraneous Cognitive Load:**
Extraneous cognitive load refers to the load that is imposed on working memory, which is extrinsic to the task at hand, and are caused by factors irrelevant to the task.

**Germane Cognitive Load:**
Germane cognitive load refers to the load that is imposed on working memory, which is pertinent to the task at hand, but is necessary for learning and understanding the task.

**Instruction:**
Refers to any training and instructional materials that are used to prepare you for using the current Electronic Medical Record (EMR) system.

## DEMOGRAPHIC QUESTIONS
## (ALL PARTICIPANTS)

---

1. What is your role?

   Medical staff
   - ☐ Consultant (Senior medical) – Neonatologist
   - ☐ Fellow
   - ☐ Senior Resident Medical Officer (SRMO)
   - ☐ Junior Resident Medical Officer (JRMO)
   - ☐ Others – *please specify*…………………………………………………………………

   Nursing staff
   - ☐ Registered Nurses
   - ☐ Clinical Nurse Specialists
   - ☐ Associate Nurse Unit Managers
   - ☐ Nurse Unit Managers
   - ☐ Clinical Support Nurses
   - ☐ Nurse Educators
   - ☐ Others – *please specify*…………………………………………………………………

2. Additional Roles *(please mark if applicable)*
   - ☐ Designer of instructional materials for [redacted] EMR system
   - ☐ Trainer of instructional materials for [redacted] EMR system

3. Which patients do you care for?
   - ☐ High risk birth
   - ☐ Intubated / ventilated
   - ☐ Non-invasive ventilation
   - ☐ Special care
   - ☐ Others - *please specify*…………………………………………………………………

4. What is your age group?

| | | |
|---|---|---|
| ☐ 20 – 30 | ☐ 41 – 50 | ☐ 61 and above |
| ☐ 31 – 40 | ☐ 51 – 60 | |

5. What is your total years of professional experience?

| | | |
|---|---|---|
| ☐ 0 – 5 years | ☐ 10 – 15 years | ☐ 20 – 25 years |
| ☐ 5 – 10 years | ☐ 15 – 20 years | ☐ 25 and above |

6. What is your total years of experience in your current role?

| | | |
|---|---|---|
| ☐ 0 – 5 years | ☐ 10 – 15 years | ☐ 20 – 25 years |
| ☐ 5 – 10 years | ☐ 15 – 20 years | ☐ 25 and above |

7. What is your total years of experience with the current [redacted] EMR system?

| | | |
|---|---|---|
| ☐ 0 – 5 years | ☐ 10 – 15 years | ☐ 20 – 25 years |
| ☐ 5 – 10 years | ☐ 15 – 20 years | ☐ 25 and above |

8. What is your total years of experience with other EMR systems?

| | | |
|---|---|---|
| ☐ 0 – 5 years | ☐ 10 – 15 years | ☐ 20 – 25 years |
| ☐ 5 – 10 years | ☐ 15 – 20 years | ☐ 25 and above |

9. Overall, how do you describe your general knowledge and literacy in computers?

| | | |
|---|---|---|
| ☐ Not knowledgeable | ☐ Knowledgeable | ☐ Very knowledgeable |

---

INTERVIEW QUESTIONS
(SET A: DESIGNERS)

**Section One:**

a. Do you know what is cognitive load? (If no, researcher explains) (If yes, probe).
b. How do you experience cognitive load and how does it impact your current role? Please explain.
c. Did you know that cognitive load can impair learning? (If no, proceed) (If yes, probe).
d. Did you know that the instructional/training materials can impose cognitive load during training activities? (If no, proceed) (If yes, probe).
e. Did you know that there are certain techniques specifically designed to manage cognitive load that is imposed by the instructional/training materials? (If no, proceed) (If yes, probe).

**Section Two:**

1. In terms of designing a solution to a problem, do you demonstrate the solution step-by-step to the learners, or do you ask them to search for the solution themselves? Please explain.
2. In terms of designing a problem, do you provide the learners with examples that are partially completed and ask them to complete the missing steps? Please explain.
3. When there are two or more sources of information, which cannot be understood in isolation from one another, do you present them separately or together? Please explain.
4. In terms of presenting information to the learners, do you use both visual and auditory modes or only one mode? Please explain.
5. Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you present that information in a spoken form or a written form? Please explain.
6. Imagine a complex information, which is intelligible on its own, how do you think repetition in presenting that information could help the learners? Please explain.
7. Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you present that information in multiple stages or in one stage? Please explain.
8. Imagine a complex information, which again contains multiple elements that cannot be understood separate from one another, do you gradually present that information from a simpler to a more complex version (e.g., in multiple progressive stages) or the main version (e.g., in one non-progressive stage)? Please explain.
9. When presenting a reproduced/replicated situation or scenario, do you gradually increase the level of similarity to the real event or the real situation? Please explain.
10. When presenting a task or a problem, do you provide the learner with different variation of the same task or problem? Please explain.
11. When presenting a new concept or a procedure, do you think asking the learners to imagine or mentally rehearsing the concept can help their learning? Please explain.
12. When presenting a new concept or procedure, do you think asking a learner to explain that concept to oneself can help their learning? Please explain.

**Section Three:**

13. How do you think the overall design of the instructional materials prepared learners to use the system?

## INTERVIEW QUESTIONS
## (SET B: TRAINERS)

---

**Section One:**

a. Do you know what is cognitive load? (If no, researcher explains) (If yes, probe).
b. How do you experience cognitive load and how does it impact your current role? Please explain.
c. Did you know that cognitive load can impair learning? (If no, proceed) (If yes, probe).
d. Did you know that the instructional/training materials can impose cognitive load during training activities? (If no, proceed) (If yes, probe).
e. Did you know that there are certain techniques specifically designed to manage cognitive load that is imposed by the instructional/training materials? (If no, proceed) (If yes, probe).

**Section Two:**

1. In terms of teaching a solution to a problem, do you demonstrate the solution step-by-step to the learners, or do you ask them to search for the solution themselves? Please explain.
2. In terms of teaching a problem, do you provide the learners with examples that are partially completed and ask them to complete the missing steps? Please explain.
3. When there are two or more sources of information, which cannot be understood in isolation from one another, do you teach them separately or together? Please explain.
4. In terms of delivering information to the learners, do you use both visual and auditory modes or only one mode? Please explain.
5. Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you deliver that information in a spoken form or a written form? Please explain.
6. Imagine a complex information, which is intelligible on its own, how do you think repetition in delivering that information could help the learners? Please explain.
7. Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you deliver that information in multiple stages or in one stage? Please explain.
8. Imagine a complex information, which again contains multiple elements that cannot be understood separate from one another, do you gradually deliver that information from a simpler to a more complex version (e.g., in multiple progressive stages) or the main version (e.g., in one non-progressive stage)? Please explain.
9. When delivering a reproduced/replicated situation or scenario, do you gradually increase the level of similarity to the real event or the real situation? Please explain.
10. When presenting a task or a problem, do you provide the learner with different variation of the same task or problem? Please explain.
11. When delivering a new concept or a procedure, do you think asking the learners to imagine or mentally rehearsing the concept can help their learning? Please explain.
12. When delivering a new concept or procedure, do you think asking a learner to explain that concept to oneself can help their learning? Please explain.

**Section Three:**

1. How do you think the overall design of the instructional materials prepared learners to use the system?

---

INTERVIEW QUESTIONS
(SET C: TRAINEES – MEDICAL / NURSING STAFF)

**Section One:**

a. Do you know what is cognitive load? (If no, researcher explains) (If yes, probe).
b. How do you experience cognitive load and how does it impact your current role? Please explain.
c. Did you know that cognitive load can impair learning? (If no, proceed) (If yes, probe).
d. Did you know that the instructional/training materials can impose cognitive load during training activities? (If no, proceed) (If yes, probe).
e. Did you know that there are certain techniques specifically designed to manage cognitive load that is imposed by the instructional/training materials? (If no, proceed) (If yes, probe).

**Section Two:**

1. In terms of learning a solution to a problem, do you like the solution to be demonstrated to you step-by-step, or do you like to search for the solution yourself? Please explain
2. In terms of learning a problem, do you like examples that are partially completed so you complete the missing steps? Please explain.
3. When there are two or more sources of information, which cannot be understood in isolation from one another, do you think you can learn them separately or together? Please explain
4. In terms of receiving information, do you think you can learn through both visual and auditory modes or only one mode? Please explain.
5. Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you learn that information when presented in a spoken form or a written form? Please explain.
6. Imagine a complex information, which is intelligible on its own, how do you think repetition in presenting or delivering that information could help your learning? Please explain.
7. Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you learn that information when presented or delivered to you in multiple stages or in one stage? Please explain.
8. Imagine a complex information, which again contains multiple elements that cannot be understood separate from one another, do you learn that information when presented or delivered from a simpler to a more complex version (e.g., in multiple progressive stages) or the main version (e.g., in one non-progressive stage)? Please explain.
9. When presented or delivered a reproduced/replicated situation or scenario, do you learn when they gradually increase the level of similarity to the real event or the real situation? Please explain.
10. When presented or delivered a task or a problem, do you learn from different variation of the same task or problem? Please explain.
11. When presented or delivered a new concept or a procedure, do you think asking you to imagine or mentally rehearsing the concept can help your learning? Please explain.
12. When presented or delivered a new concept or procedure, do you think asking you to explain that concept to yourself can help your learning? Please explain.

**Section Three:**

1. How do you think the overall design of the instructional materials prepared you to use the system?

Mapping the interview questions to the wordings for each actor

| **Sections** | **Objectives** | **Descriptions** | **Questions for Designers** | **Questions for Trainers** | **Questions for Trainees** |
|---|---|---|---|---|---|
| Section One | Interpretation of cognitive load | Awareness and experience | Do you know what is cognitive load? (If no, researcher explains) (If yes, probe). | | |
| | | | How do you experience cognitive load and how does it impact your current role? Please explain. | | |
| | | | Did you know that cognitive load can impair learning? (If no, proceed) (If yes, probe). | | |
| | | | Did you know that the instructional/training materials can impose cognitive load during training activities? (If no, proceed) (If yes, probe). | | |
| | | | Did you know that there are certain techniques specifically designed to manage cognitive load that is imposed by the instructional/training materials? (If no, proceed) (If yes, probe). | | |
| Section Two | Views on instructional techniques*<br><br>*Set of six techniques for reducing extraneous load | 1. Worked Example (T1): Provide learners with a *step-by-step* solution to a problem rather than asking them to search for the solution themselves. | In terms of *designing* a solution to a problem, do you demonstrate the solution step-by-step to the learners, or do you ask them to search for the solution themselves? Please explain. | In terms of *teaching* a solution to a problem, do you demonstrate the solution step-by-step to the learners, or do you ask them to search for the solution themselves? Please explain. | In terms of *learning* a solution to a problem, do you like the solution to be demonstrated to you step-by-step, or do you like to search for the solution yourself? Please explain. |
| | | 2. Problem Completion (T2): Provide learners with *partially-completed* examples and ask them to complete the steps. | In terms of *designing* a problem, do you provide the learners with examples that are partially completed and ask them to complete the missing steps? Please explain. | In terms of *teaching* a problem, do you provide the learners with examples that are partially completed and ask them to complete the missing steps? Please explain. | In terms of *learning* a problem, do you like examples that are partially completed so you complete the missing steps? Please explain. |
| | | 3. Split-attention (T3): Replace multiple sources of information, which are distributed across space to time and unintelligible in isolation, with *single, integrated / synchronised* source. | When there are two or more sources of information, which cannot be understood in isolation from one another, do you *present* them separately or together? Please explain. | When there are two or more sources of information, which cannot be understood in isolation from one another, do you *teach* them separately or together? Please explain. | When there are two or more sources of information, which cannot be understood in isolation from one another, do you think you can *learn* them separately or together? Please explain. |
| | | 4. Modality (T4): Replace presentations of information that engage only visual or auditory channels (i.e. unimodal) with those engaging both *visual and auditory* channels (i.e. multimodal) of WM. | In terms of *presenting* information to the learners, do you use *both* visual and auditory modes or *only one* mode? Please explain. | In terms of *delivering* information to the learners, do you use *both* visual and auditory modes or *only one* mode? Please explain. | In terms of *receiving* information, do you think you can *learn* through *both* visual and auditory modes or *only one* mode? Please explain. |
| | | 5. Transient Information (T5): Replace transient form of information (e.g., verbal, or auditory instructions) with *non-transient* forms (e.g., written instruction). | Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you *present* that information in a *spoken* form or a *written* form? Please explain. | Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you *deliver* that information in a *spoken* form or a *written* form? Please explain. | Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you *learn* that information when presented in a *spoken* form or a *written* form? Please explain. |
| | | 6. Redundancy (T6): Replace multiple sources of information that are intelligible on their own (i.e. self-contained) with a *single self-explanatory* source. | Imagine a complex information, which is intelligible on its own, how do you think repetition in *presenting* that information could help the learners? Please explain. | Imagine a complex information, which is intelligible on its own, how do you think repetition in *delivering* that information could help the learners? Please explain. | Imagine a complex information, which is intelligible on its own, how do you think repetition in *presenting* or *delivering* that information could help your learning? Please explain. |

| Sections | Objectives | Descriptions | Questions for Designers | Questions for Trainers | Questions for Trainees |
|---|---|---|---|---|---|
| | *Set of three techniques for managing intrinsic load | 1. Isolated Elements (T7): Present complex information with multiple interacting elements sequentially from *isolated non-interacting* elements to *all interacting* elements. | Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you *present* that information in *multiple stages* or in *one stage*? Please explain. | Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you *deliver* that information in *multiple stages* or in *one stage*? Please explain. | Imagine a complex information, which contains multiple elements that cannot be understood separate from one another, do you learn that information when *presented* or *delivered* to you in *multiple stages* or in *one stage*? Please explain. |
| | | 2. Simple-to-complex progression (T8): Present complex learning tasks progressively from a *simpler version* to a more complex version of that task. | Imagine a complex information, which again contains multiple elements that cannot be understood separate from one another, do you gradually *present* that information from a simpler to a more complex version (e.g., in multiple progressive stages) or the main version (e.g., in one non-progressive stage)? Please explain. | Imagine a complex information, which again contains multiple elements that cannot be understood separate from one another, do you gradually *deliver* that information from a simpler to a more complex version (e.g., in multiple progressive stages) or the main version (e.g., in one non-progressive stage)? Please explain. | Imagine a complex information, which again contains multiple elements that cannot be understood separate from one another, do you *learn* that information when *presented* or *delivered* from a simpler to a more complex version (e.g., in multiple progressive stages) or the main version (e.g., in one non-progressive stage)? Please explain. |
| | | 3. Low- to high-physical fidelity progression (T9): Present complex learning tasks progressively from *low- to high-fidelity* environments. | When *presenting* a reproduced/replicated situation or scenario, do you gradually increase the level of similarity to the real event or the real situation? Please explain. | When *delivering* a reproduced/replicated situation or scenario, do you gradually increase the level of similarity to the real event or the real situation? Please explain. | When presented or delivered a reproduced/replicated situation or scenario, do you learn when they gradually increase the level of similarity to the real event or the real situation? Please explain. |
| | *Set of three techniques for optimising germane load | 1. Variability (T10): Provide learners with *a series of tasks that differ from one another* on all dimensions in which tasks differ in the real world, rather than a series of tasks with only similar surface features. | When *presenting* a task or a problem, do you provide the learner with different variation of the same task or problem? Please explain. | When *presenting* a task or a problem, do you provide the learner with different variation of the same task or problem? Please explain. | When *presented* or *delivered* a task or a problem, do you learn from different variation of the same task or problem? Please explain. |
| | | 2. Imagination (T11): Encourage learners to engage in imagining or mentally rehearsing a task, rather than only studying a task. | When *presenting* a new concept or a procedure, do you think asking the learners to imagine or mentally rehearsing the concept can help their learning? Please explain. | When *delivering* a new concept or a procedure, do you think asking the learners to imagine or mentally rehearsing the concept can help their learning? Please explain. | When *presented* or *delivered* a new concept or a procedure, do you think asking you to imagine or mentally rehearsing the concept can help your learning? Please explain. |
| | | 3. Self-explanation (T12): Provide learners with prompt to self-explain a given concept or procedure related to a task. | When *presenting* a new concept or procedure, do you think asking a learner to explain that concept to oneself can help their learning? Please explain. | When *delivering* a new concept or procedure, do you think asking a learner to explain that concept to oneself can help their learning? Please explain. | When *presented* or *delivered* a new concept or procedure, do you think asking you to explain that concept to yourself can help your learning? Please explain. |
| Section Three | Miscellaneous | Suggestions for improvements | How do you think the overall design of the instructional materials prepared learners to use the system? | How do you think the overall design of the instructional materials prepared learners to use the system? | How do you think the overall design of the instructional materials prepared you to use the system? |

## Appendix G: The Coding Environment in NVivo (Sample illustration)

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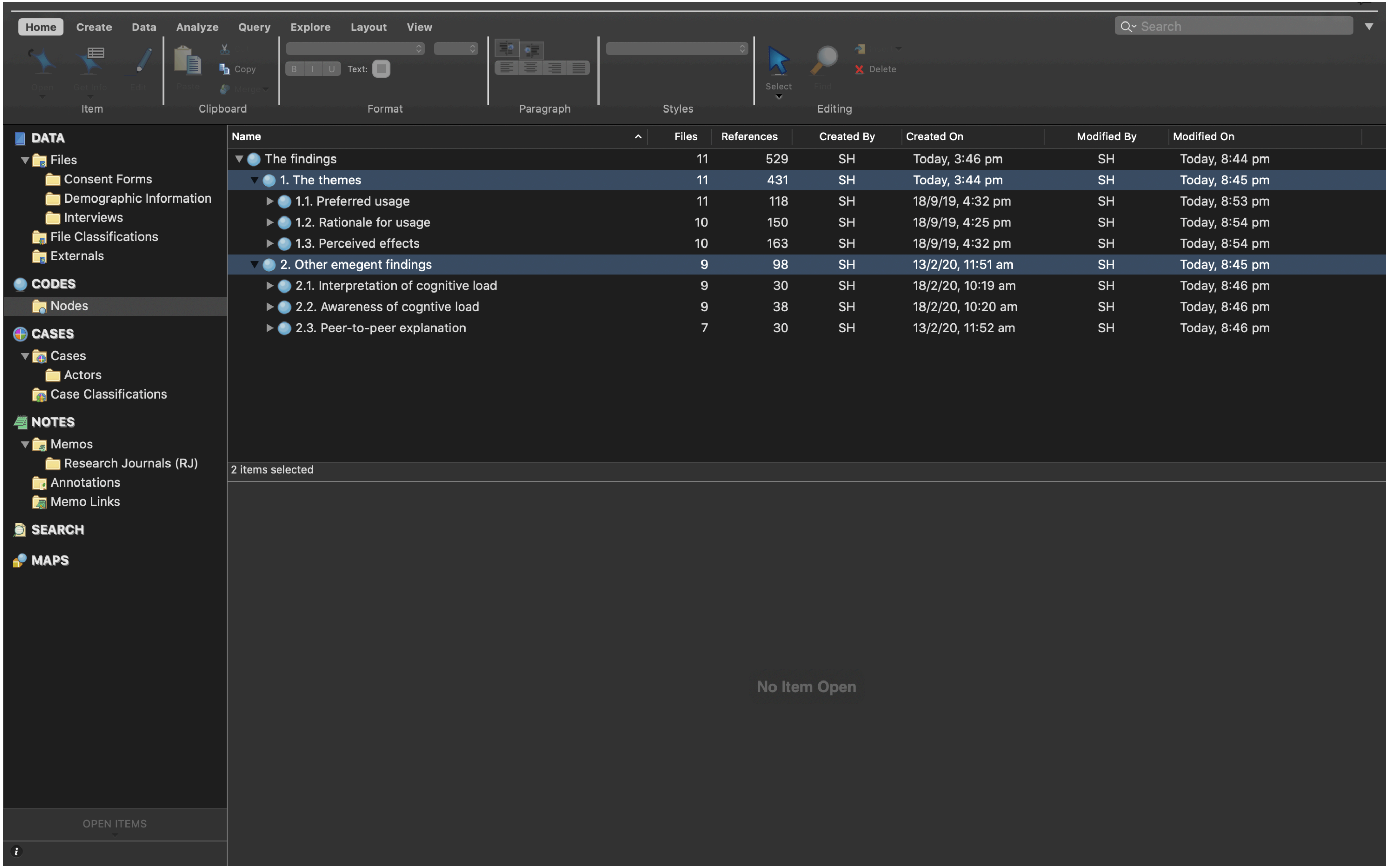
Home
Create
Data
Analyze
Query
Explore
Layout
View
Search
Copy
Text:
Delete
Select
Item
Clipboard
Format
Paragraph
Styles
Editing
DATA
Files
Consent Forms
Demographic Information
Interviews
File Classifications
Externals
CODES
Nodes
CASES
Cases
Actors
Case Classifications
NOTES
Memos
Research Journals (RJ)
Annotations
Memo Links
SEARCH
MAPS
OPEN ITEMS
Name | Files | References | Created By | Created On | Modified By | Modified On
The findings | 11 | 529 | SH | Today, 3:46 pm | SH | Today, 8:44 pm
1. The themes | 11 | 431 | SH | Today, 3:44 pm | SH | Today, 8:45 pm
1.1. Preferred usage | 11 | 118 | SH | 18/9/19, 4:32 pm | SH | Today, 8:53 pm
1.2. Rationale for usage | 10 | 150 | SH | 18/9/19, 4:25 pm | SH | Today, 8:54 pm
1.3. Perceived effects | 10 | 163 | SH | 18/9/19, 4:32 pm | SH | Today, 8:54 pm
2. Other emegent findings | 9 | 98 | SH | 13/2/20, 11:51 am | SH | Today, 8:45 pm
2.1. Interpretation of cognitive load | 9 | 30 | SH | 18/2/20, 10:19 am | SH | Today, 8:46 pm
2.2. Awareness of cogntive load | 9 | 38 | SH | 18/2/20, 10:20 am | SH | Today, 8:46 pm
2.3. Peer-to-peer explanation | 7 | 30 | SH | 13/2/20, 11:52 am | SH | Today, 8:46 pm
2 items selected
No Item Open

## Appendix H: The Codebook (Excerpt)

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Theme One: Preferred Usage
Indications of preferences across all techniques by all actors

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| 1 | Theme One | Preferred Usage | This overarching theme capturing the *indications of preferences* for using techniques and describes it from the points of view of actors. It answers *which* techniques are preferred to be used by the actors. | 11 | 118 | P01 to P09 | - |
| 2 | T1 | Worked Example | The parent node containing all child nodes and references to actors' views on *Worked Example*. This technique aims to reduce the extraneous load that is imposed by the instructional materials on learners by providing learners with a *step-by-step* solution to a problem rather than asking them to search for the solution themselves. | 9 | 9 | P01 to P09 | - |
| 3 | T1-U1 | Preference for using either 'step-by-step' or 'search for solution' | The child node containing all references to using either 'step-by-step' or 'search for solution'. | 5 | 5 | 5 | Shown below: |
| 4 | T1-U1-01 | Using 'step-by-step' only | The references to using 'step-by-step' only. | 3 | 3 | P02, P07, P09 | - P02 (Tr-NS): I would prefer if somebody gives you a solution step-by-step.<br>- P07 (Ds-NS): I would do step by step.<br>- P09 (Te-MS): Step by step, I guess, yeah. |
| 5 | T1-U1-02 | Using 'search for solution' only | The references to using 'search for solution' only. | 2 | 2 | P03, P05 | - P03 (Te-MS): I think the second option [search for solution].<br>- P05 (Te-NS): I usually prefer to search for it. |
| 6 | T1-U2 | Preference for using both 'step-by-step' and 'search for solution' | The child node containing all references to using both 'step-by-step' and 'search for solution'. | 4 | 4 | 4 | Shown below: |
| 7 | T1-U2-01 | Using 'step-by-step' followed by 'search for solution' | The references to using 'step-by-step' first and then supplementing it with 'search for solution'. | 1 | 1 | P06 | - P06 (Te-NS): I prefer a step-by-step but then I need to go in. |
| 8 | T1-U2-02 | Using 'search for solution' followed by 'step-by-step' | The references to using 'search for solution' first and then supplementing it with 'step-by-step'. | 3 | 3 | P01, P04, P08 | - P01 (Ds-MS): […] they're asked to search for the solution themselves. And then, if they have difficulty finding it, then I would take them through step-by-step.<br>- P04 (Tr-NS): I prefer to search myself, and then, if I can't find it ask.<br>- P08 (Te-MS): I prefer to search for it myself but then, if I can't find it, be shown step-by-step by someone. |

Theme One: Preferred Usage
Indications of preferences across all techniques by all actors

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| 9 | T2 | Problem Completion | The parent node containing all child nodes and references to actors' views on *Problem Completion*. This technique aims to reduce the extraneous load that is imposed by the instructional materials on learners by providing learners with *partially-completed* examples and ask them to complete the steps. | 9 | 9 | P01 to P09 | - |
| 10 | T2-U1 | Preference for using problem completions | The child node containing all references to using problem completions. | 5 | 5 | 5 | Shown below: |
| 11 | T2-U1-01 | Using 'partially-completed examples' | The references to using 'partially-completed examples'. | 5 | 5 | P01, P02, P03, P04, P09 | - P01: I do that, yes.<br>- P02: Well, I guess if it's partially-completed, filling in the blanks is a good way of learning. As long it's not too difficult.<br>- P03: Oh yeah. I think that also works in a way that you are involved in that whole learning process actively rather than being a passive listener.<br>- P04: Yes. Yeah. Yeah.<br>- P09: Yes, I would say so. |
| 12 | T2-U2 | No preference for using problem completions | The child node containing all references to NOT using problem completions. | 4 | 4 | 4 | - Shown below: |
| 13 | T2-U2-01 | Not using 'partially-completed examples' | The references to NOT using 'partially-completed examples'. | 4 | 4 | P05, P06, P07, P08 | - P05: No, I think I'd like to, I'd like to start at the beginning.<br>- P06: No. I need to do things like from start to finish.<br>- P07: I would have started from the beginning, not with halfway through the problem.<br>- P09: No, I prefer, if it's an example, I want it all there. |
| 14 | T3 | Split-attention | The parent node containing all child nodes and references to actors' views on *Split-attention*. This technique aims to reduce the extraneous load that is imposed by the instructional materials on learners by replacing multiple sources of information, which are distributed across space to time and unintelligible in isolation, with *single, integrated / synchronised* source. | 9 | 9 | P01 to P09 | - |
| 15 | T3-U1 | Preference for split-attention | The child node containing all references to using split-attention. | 8 | 8 | 8 | Shown below: |

Theme One: Preferred Usage
Indications of preferences across all techniques by all actors

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| 16 | T3-U1-01 | Using 'integrated' source of information | The references to preferring integrated source of information. | 8 | 8 | P01, P02, P03, P04, P05, P07, P08, P09 | - P01: I kind of present them together.<br>- P02: Well, if they're intermingled, you should have them together really.<br>- P03: Together.<br>- P04: Yeah, no I need them together.<br>- P05: Oh, yes. So, they need to be together. Yes, I prefer them together.<br>- P07: I'm thinking you would need to present them together.<br>- P08: Um, I haven't thought about it. Probably together.<br>- P09: Probably together. |
| 17 | T3-U2 | No preference for split-attention | The child node containing all references to NOT using split-attention. | 1 | 1 | 1 | Shown below: |
| 18 | T3-U2-01 | Using 'separated' source of information. | The references to preferring non-integrated source of information. | 1 | 1 | P06 | - P06: I'd say, like separately. As in separately, probably the same session, so I can get an understanding. |
| 19 | T4 | Modality | The parent node containing all child nodes and references to actors' views on *Modality*. This technique aims to reduce the extraneous load that is imposed by the instructional materials on learners by replacing presentations of information that engage only visual or auditory channels (unimodal) with those engaging both *visual and auditory* channels (multimodal) of WM. | 9 | 9 | P01 to P09 | - |
| 20 | T4-U1 | Preference for modality | The child node containing all references to using modality. | 8 | 8 | 8 | Shown below: |
| 21 | T4-U1-01 | Using 'multimodal' presentation of information | All references to preferring multimodal presentation of information (e.g., both visual and auditory channels) | 8 | 8 | P01, P02, P03, P04, P05, P07, P08, P09 | - P01: Both have to be together.<br>- P02: I prefer to receive information in both forms.<br>- P03: Yes, both.<br>- P04: Both.<br>- P05: Both.<br>- P07: It can help them yeah. (Answering a probing question: So, you think combining the two, for example, showing it by doing that and using the visual modes of giving information and then both auditory can help them?<br>- P08: Both.<br>- P09: I prefer, prefer both. |
| 22 | T4-U2 | No preference for modality | The child node containing all references to NOT using modality. | 1 | 1 | 1 | Shown below: |

Theme One: Preferred Usage
Indications of preferences across all techniques by all actors

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| 23 | T4-U2-01 | Using 'unimodal' presentation of information | All references to preferring unimodal presentation of information (e.g., either visual or auditory channels). | 1 | 1 | P06 | - P06: The visual. |
| 24 | T5 | Transient Information | The parent node containing all child nodes and references to actors' views on *Transient Information*. This technique aims to reduce the extraneous load that is imposed by the instructional materials on learners by replacing transient form of information (e.g., verbal, or auditory instructions) with *non-transient* forms (e.g., written instruction). | 8 | 8 | P01 to P09 | - |
| 25 | T5-U1 | Preference for non-transient information | The child node containing all references to preferring non-transient information. | 5 | 5 | 5 | Shown below: |
| 26 | T5-U1-01 | Using 'non-transient' form of information | All references to preferring non-transient form of information (e.g., written texts). | 5 | 5 | P02, P04, P05, P08, P09 | - P02: I think in a written form to start with,<br>- P04: Probably written.<br>- P05: Written.<br>- P08: Probably written, if it's complex.<br>- P09: Written. |
| 27 | T5-U2 | Preference for transient information | The child node containing all references to using transient information. | 1 | 1 | 1 | Shown below: |
| 28 | T5-U2-01 | Using 'transient' form of information | All references to preferring transient form of information (e.g., spoken words). | 1 | 1 | P06 | - P06: Spoken [form]. |
| 29 | T5-U3 | Preference for both non-transient and transient form of information | The child node containing all references to both using non-transient and transient information. | 3 | 3 | 3 | Shown below: |
| 30 | T5-U3-01 | Using both 'transient' and 'non-transient' form of information | All references to preferring both non-transient and transient form of information (e.g., both written texts and spoken words). | 3 | 3 | P01, P03, P07 | - P01: I would say both actually.<br>- P03: I think probably a combination of both.<br>- P07: I would prefer to provide written and verbal communication […] |
| 31 | T6 | Redundancy | The parent node containing all child nodes and references to actors' views on *Redundancy*. This technique aims to reduce the extraneous load that is imposed by the instructional materials on learners by replacing multiple sources of information that are intelligible on their own (i.e. self-contained) with a *single self-explanatory* source. | 9 | 21 | P01 to P09 | - |

Theme One: Preferred Usage
Indications of preferences across all techniques by all actors

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| 32 | T6-U1 | Preference for sufficiently repeating information | The child node containing all references to both using non-transient and transient information. | 9 | 21 | 9 | Shown below: |
| 33 | T6-U1-01 | Using 'sufficient repetition' of information | All references to preferring sufficient repetition of, as opposed to repetitive, information. | 9 | 21 | P01, P02, P03, P04, P05, P06, P07, P08, P09 | - P01: I think repetition, yes.<br>- P01: […] and then the repetition would be on a need-to basis. Maybe a refresher, Q&A kind of session.<br>- P02: Um [pasue]. I guess we all like it to be repeated usually. I mean when something's said to you, you interpret it, initially how you think it is, and sometimes you don't perhaps give it any critical thinking. But then when somebody reiterates it again perhaps in a slightly different way you take it on board a bit better. And so therefore, I think, you know, things are repeated, yes you're more likely to understand it, and therefore be able to work through whatever might be telling you for that or you retain what it is.<br>- P02: […]Well, it all depends on the individual really. But for some of us yes, we'd like to think oh yes we've grabbed that let's move on to the next thing. I don't want to hear it again.<br>- P02: Yes, I guess I can go back and think if you have people lecturing you repeat something and then they repeat it again.<br>- P03: I think there is a limit to how many times you can repeat information in a given day.<br>- P03: However, if I was reading the same topic over and over again on the same day. I wouldn't necessarily retain enough information that's too much repetition.<br>- P04: Because then it just becomes, even though sometimes it could be a bit of rote learning and sometimes that is dangerous when you rote learn something because you're not thinking of the reasons behind what you're doing is also really important.<br>- P05: Ah yeah. Repeating would be helpful if I am relying just on the auditory. Then definitely it would need to be repeated probably more than a couple of times though.<br>- P05: […] I think it could potentially become frustrating hearing the same thing over and over again, […]<br>- P06: I think it, repeating it does help me.<br>- P06: […]Y es, and it can be quite frustrating, which might then switch your mind off as in because I keep hearing the same thing over and over. |

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| | | | | | | | - P07: […]it helps them to create the whole picture, like a jigsaw puzzle.<br>- P07: […] I think it can be it can stop their learning,<br>- SH: So if my if my understanding is correct on what you said is that, there is definitely a limit of a repeating certain information, but there is a link between that particular limit and that the time that they get the overall picture of the problem. Is that right?<br>- P07: Yes.<br>- P08: Repetition is the key to learning.<br>- P08: […] Probably sticks in more because you're making fun of it in your head for how much it's gone, it was repeated. But if it's just repeated 'one, one, one, one, one straight after the other' then you just shut off after a couple of times.<br>- P09: I think, I have in the past certainly learned through repetition. Particularly, through study and studying for fellowship exams. That's a technique I've certainly used.<br>- P09: I think the only way I could learn that was through repetition.<br>- P09 […] So, then it can become a bit boring as well, and can have a tendency to zone out a bit if things are repeated too much. I think it's a balance.<br>- P09: […] But sometimes if you feel like you've already understood it, then it's something you might ignore it; as I know if you're watching the presentation. |
| 34 | Q7 | Isolated Elements | The parent node containing all child nodes and references to actors' views on *Isolated Elements*. This technique aims to manage the intrinsic load that is imposed by the instructional materials on learners by presenting complex information with multiple interacting elements sequentially from *isolated non-interacting elements* to all interacting elements. | 9 | 9 | P01 to P09 | - |
| 35 | Q7-U1 | Preference for sequential presentation of information | The child node containing all references to sequencing presentation of information using multiple stages. | 6 | 6 | 6 | Shown below: |
| 36 | Q7-U1-01 | Using 'multiple' stages | All references to preferring sequential presentation of information (e.g., in multiple stages). | 6 | 6 | P01, P02, P03, P04, P07, P08 | - P01: In multiple steps.<br>- P02: I'd like to see all the stages because then you have an understanding of how much work may be involved.<br>- P03: […] if you have a very complex EMR system, for |

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| | | | | | | | example, then perhaps the staged delivery of the informatior is more helpful just to avoid being overloaded with information in the one go. What I find is that at some point during, receiving the information your brain just like goes is too much. I cannot remember all this.<br>- P04: I want it all at once, but then perhaps broken down into separate second. So, I can be told overall this is what we're looking at, and this is the big picture. So, I've got an idea what we'll do is we'll break down each of these elements now. So, then you can understand each element and then we'll put it back together at the big picture.<br>- P07 I would start small and continue to build on to it.<br>- P08: Probably in multiple stages but starting with an overview. |
| 37 | Q7-U2 | Preferences for non-sequential presentation of information | The child node containing all references to non-sequencing presentation of information using a single stage. | 3 | 3 | 3 | Shown below: |
| 38 | Q7-U2-01 | Using 'single' stage | All references to preferring non-sequential presentation of information (e.g., in a single stage). | 3 | 3 | P05, P06, P09 | - P05: One stage.<br>- P06: One.<br>- P09: "Probably in a single stage, but with associated resource<br>- SH: What do you mean by the 'associated resources'?<br>- P09: I will say from going [pause], if I'm going to say a cours or module, I would prefer it not to be spread out too long, whereas I feel like I'm quite time-poor, but I would like that be aside take away the materials that I can revisit." |
| 39 | Q8 | Low- to high-physical fidelity progression | The parent node containing all child nodes and references to actors' views on *Low- to high-physical fidelity*. This technique aims to manage the intrinsic load that is imposed by the instructional materials on learners by presenting complex learning tasks progressively from *low- to high-fidelity* environments. | 8 | 8 | P01 to P09 (except P03) | - |
| 40 | Q8-U1 | Preferences for low- to high-physical fidelity | The child node containing all references to low- to high-physical fidelity. | 6 | 6 | 6 | Shown below |
| 41 | Q8-U1-01 | Using 'low- to high-physical fidelity' | All references to preferring low- to high-physical fidelity (e.g., with progression) | 6 | 6 | P01, P02, P04, P05, P06, P07 | - P01: So, the main thing really is that we have a test domain for the system. So, it's exactly the same as the real system except for few and that's not actually. So, what I do is that I run through a real is based on a real case and then they have to enter information into the patient notes. And then, read information from the patient notes. But this |

Theme One: Preferred Usage
Indications of preferences across all techniques by all actors

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| | | | | | | | patient is actually in the test domain.<br>- P02: I just [pause] we'd like the big picture. But, I guess for the information and putting it in, it's easier to do it gradually in an Electronic Medical Records. I can see that from practice and trial. But, you just still going to know where you're going with it all.<br>- P04: Yes. So, I always say, start simple and use it as a buildin[g] block.<br>- P05: The same way, yeah. At the beginning.<br>- P06: I think the similarities should increase with your learnin[g]<br>- P07: I would start small and continue to build on to it. |
| 42 | Q8-U2 | Preferences for high-physical fidelity | The child node containing all references to high-physical fidelity. | 2 | 2 | 2 | Shown below |
| 43 | Q8-U2-01 | Using 'high-physical fidelity' | References to high-physical fidelity (e.g., with no progression) | 3 | 3 | P08, P09 | - P08: Probably the real case from the beginning.<br>- P09: I think the same is the real case. |
| 44 | Q9 | Simple-to-complex progression | The parent node containing all child nodes and references to actors' views on *Simple to complex*. This technique aims to manage the intrinsic load that is imposed by the instructional materials on learners by presenting complex learning tasks progressively from a *simpler version* to a more complex version of that task. | 9 | 9 | P01 to P09 | - |
| 45 | Q9-U1 | Preferences for simple to complex progression | The child node containing all references to simple-to-complex progression in presenting information. | 8 | 8 | 8 | - Shown below: |
| 46 | Q9-U1-01 | Using 'simple-to-complex' progression | All references to preferring simple-to-complex progression in presentation information. | 8 | 8 | P02, P03, P04, P05, P06, P07, P08, P09 | - P02: Gradually, yes.<br>- P03: Yes, it's always best to start out simple.<br>- P04: Yeah, again the same as before. And you may start by saying this is the big picture. And then breaking it down and building up.<br>- P05: Ah, yeah probably gradual, probably increase,<br>- P06: Yes, very similar, yeah. [referring to Q8, same codes].<br>- P07: I think the best way to do it, is to introduce [gradually]. But in reality, in the workplace, probably just unfortunately go with the whole.<br>- P08: Yeah, it's better to start with simpler stuff.<br>- P09: So, it's probably easier to be introduced to new concepts in a gradual manner. |

Theme One: Preferred Usage
Indications of preferences across all techniques by all actors

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| 47 | Q9-U2 | Preferences for no progression | The child node containing all references to no progression in presenting information. | 1 | 1 | 1 | - Shown below: |
| 48 | Q9-U2-01 | Using 'complex' with no progression | All references to preferring complex progression in presentation information. | 1 | 1 | P01 | - P01: Just solution.<br>- SH: [Q9 - p1] The level of complexity does not affect the presentation of that?<br>- P01: [A9 - p1] No. |
| 49 | T10 | Variability | The parent node to contain all child nodes and references to actors' views on *Variability*. This technique aims to optimise the germen load that is imposed by the instructional materials on learners by providing learners with *a series of tasks that differ from one another* on all dimensions in which tasks differ in the real world, rather than a series of tasks with only similar surface features. | 9 | 9 | P01 to P09 | - |
| 50 | T10-U1 | Preferences for variability over a learning task | The child node containing all references to variability over a learning task. | 6 | 6 | 6 | Shown below: |
| 51 | T10-U1-01 | Using 'high variability' | All references to preferring high variability over a learning task. | 6 | 6 | P02, P04, P05, P06, P08, P09 | - P02: Well I guess that helps you understand it better if you've got different variations.<br>- P04: Yes. So, if there are multiple ways of doing it. You know, they always say there's lots of ways to skin a cat. For example, I might not understand that first well but then put it in a different way in a different way again can really help.<br>- P05: Yes. So, it's probably good to learn different ways.<br>- P06: Different ways, yes.<br>- P08: Yes.<br>- P09: Yes, I think so. I quite (pause) appreciate seeing different tasks or problems from a different angle. |
| 52 | T10-U2 | Preferences for no variability over a learning task | The child node containing all references to no variability over a learning task. | 3 | 3 | 3 | - |
| 53 | T10-U2-01 | Using 'low variability' | All references to preferring low variability over a learning task. | 3 | 3 | P01, P03, P07 | - P01: I try not to, actually.<br>- P03: I think when you're training everyone should stick to presenting the same way of doing something. Because then it achieves consistency and there's no confusion.<br>- P07: It can confuse you and it can help you. |
| 54 | T11 | Imagination | The parent node to contain all child nodes and references to actors' views on *Imagination*. This technique aims to optimise the germen load that is imposed by the instructional | 8 | 8 | P01 to P09 (except R02) | - |

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
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| | | | materials on learners by encouraging learners to engage in imagining or mentally rehearsing a task, rather than only studying a task. | | | | |
| 55 | T11-U1 | Preferences for using imagination | The child node containing all references to using imagination | 7 | 7 | 7 | Shown below: |
| 56 | T11-U1-01 | Using 'imagination' to mentally rehears a task | All references to using imagination to mentally rehearse a task (e.g., imagination helps). | 7 | 7 | P01, P03, P04, P05, P06, P07, P09 | - P01: Yeah, it helps.<br>- P03: Yeah.<br>- P04: Absolutely.<br>- P05: Yeah, Definitely.<br>- P06: Yes.<br>- P07: Well, I think that helps them to work through in their own mind, how they're going to do it in the work place, and how it relates to, for them, to think through mentally rehearse what you're gonna do in the workplace. I mean that's a technique that I will use, and I've been taught to use that.<br>- P09: Yeah, I think so. |
| 57 | T11-U2 | Preferences for not using imagination | The child node containing all references to NOT using imagination | 1 | 1 | 7 | Shown below: |
| 58 | T11-U2-01 | Using no 'imagination' to mentally rehears a task | All references to NOT using imagination to mentally rehearse a task (e.g., imagination does not help). | 1 | 1 | P08 | - P08: I'm not as, personally I'm not as, imagery learning. |
| 59 | T12 | Self-explanation | The parent node to contain all child nodes and references to actors' views on *Self-explanation*. This technique aims to optimise the germen load that is imposed by the instructional materials on learners by learners with prompt to self-explain a given concept or procedure related to a task. | 9 | 9 | P01 to P09 | - |
| 60 | T12-U1 | Preference for using self-explanation | The child node containing all references to sing self-explanation to learn a concept or procedure related to a task. | 9 | 9 | 9 | Shown below: |
| 61 | T12-U1-01 | Using 'self-explanation' | References to using self-explanation to learn a concept or procedure related to a task (e.g., self-explanation helps). | 9 | 9 | P01, P02, P03, P04, P05, P06, P07, P08, P09. | - P01: Yes, I think so.<br>- P02: I'm sure it does.<br>- P03: Yes.<br>- P04: Yeah. And I'll do that a lot. Yeah and I'll write down so I'll write key parts down of what's just been said and then I can work through exactly what does that mean.<br>- P05: Yes. Yes, it's talking through it. Quite often in my brain I'm talking through it as I say if I need to also jotting |

| No. | ID | Name | Description | Files | References | Participant | Data Extracts |
|---|---|---|---|---|---|---|---|
| | | | | | | | it down that I'm constantly thinking things through like the brain always ticking through thinking, thinking, through each step.<br>- P06: Yeah, I do yeah.<br>- P07: I would.<br>- P08: Yes.<br>- P09: Probably. Yeah. |