Chapter 97
Cognitive Load Theory in E-Learning

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ABSTRACT

Cognitive load can be assessed and monitored using a multitude of subjective (self-reports, i.e. Hart & Staveland, 1988; Paas, 1992) and more objective methods (dual tasks, eye-tracking, heart-rate measurements, skin conductance measurements, cf. Brünken, Plass, & Leutner, 2003; Beatty, 1982, Paas, van Merriënboer, & Adam, 1994), either during the learning or afterwards, so that instruction can be optimized based on mental effort data using iterative design (a cyclic process of prototyping, testing, analyzing, and refining a product or process, ultimately improving the quality and functionality of the design). Computer simulations provide an excellent environment to apply CLT principles. However, such e-environments are technically complex and therefore add to extraneous load. Separating the technical knowledge of how to use the computer interface from the actual conceptual knowledge using sequencing should reduce this load to a reasonable extent (cf. Clarke, Ayres & Sweller, 2006). The authors provide guidelines on how to use CLT in the design of e-environments and discuss what future directions can be taken to further optimize the design of such environments.

INTRODUCTION

There exist 3 major areas of research regarding CLT: how to lower load on working memory, how to stimulate the consolidation of new information in mental schemata in long-term memory and how to measure cognitive load for design purposes. CLT effectively deals with the limitations that are induced by working memory by creating instructions that lower the intrinsic (content-based), extraneous (presentation-based) and germane (information consolidation-based) cognitive load on working memory (Chandler & Sweller, 1991;

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Sweller, Van Merriënboer & Paas, 1998; Kirschner, 2002, Van Merriënboer, Kirschner, & Kester, 2003). This can be done by dividing the whole task in separate learning tasks that are whole-task experiences but increase in difficulty as experience is gained (4C/ID; Van Merriënboer, 1997), by using worked-examples (Paas & van Merriënboer, 1994; Sweller & Cooper, 1985), avoiding splits of attention (Chandler & Sweller, 1991), avoiding redundancy (Chandler & Sweller, 1991), and using multimedia instead of only one modality (Mayer, 1997).

Consolidation of new knowledge in schemata in long-term memory can be facilitated by e.g. using scaffolding and fading support (Van Merrienboer, Clark & de Croock, 2002), just-in-time information presentation (Kester, Kirschner, van Merriënboer, 2001), and/or using increasingly incomplete examples that learners have to complete so that the different steps of which the mental model should consist are made explicit (Van Merriënboer & Kramer, 1990).

Cognitive load theory (CLT, Sweller, Van Merriënboer, & Paas, 1998) is a theoretical framework of learning based on human cognitive architecture. It assumes that learning is constrained by the limited processing capacity of the learner's cognitive architecture. The cognitive capacity a person has available to actively process and store information is limited to between 7±2 familiar elements (Miller, 1956) and 4±1 elements if they are novel (Cowan, 2001). As a consequence, instruction that places a high demand on this capacity, either by including too much or too complex information, or by presenting it in ways that do not contribute to learning or even hamper learning, reduces the acquisition of new knowledge or skill. The aim of researchers in the field of CLT has, therefore, been to develop techniques to manage the cognitive load (CL) imposed by a learning task in order to facilitate learning. Because user interfaces in E-learning are often technologically complex compared to the traditional paper-based materials (e.g., use of multi-media, multitasks or multi-facetted tasks, and/or an often non-linear information organization), the instructional principles derived from CLT are particularly relevant and useful for designing effective E-learning environments. Fortunately, E-learning environments can accommodate the majority of CLT principles in relatively simple ways (Jochems, Van Merriënboer, & Koper, 2004).

This chapter first introduces CLT and its main players, second we will elaborate on how to measure CLT, third we will discuss the main effects of CL and how to deal with them in e-learning, fourth we will discuss the 4C/ID model that offers a standardized approach on how to design new e-learning materials while taking the effects of CL into account, and finally the chapter end with our perspective on future approaches that can be taken in CLT and e-learning.

COGNITIVE LOAD THEORY

CLT describes learning of complex cognitive tasks, in which the number of interactive information elements that need to be processed simultaneously before meaningful learning can commence often overwhelms learners. According to CLT, individual learning depends on the limited processing capacity of the learner's cognitive architecture and the CL imposed by a task. According to the Atkinson and Shiffrin model (1971) the cognitive architecture consists of an effectively unlimited long-term memory (LTM), which interacts with a working memory (WM) that is very limited in both *capacity* (Baddeley & Hitch, 1974; Cowan, 2001; Miller, 1956) and *duration* (Peterson & Peterson, 1959). For new, yet to be learned information, processing capacity is limited to only 4±1 information elements, and if not rehearsed, the information is lost within 30 seconds (Cowan, 2001). LTM consists of cognitive schemata schemas (Van Lehn, 1996) that store and organize knowledge by incorporating multiple elements of information into a single element (also referred to as a *chunk*; Miller, 1956) with a specific function (i.e.,