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Theory for Simulation

Using Cognitive Load Theory to Inform Simulation Design and Practice

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Abstract: Cognitive science has long sought to explore the ways in which information is processed by the brain and to generate from this overarching constructs and models of thinking and learning. This article explores cognitive load theory, one approach to understanding learning, and articulates ways in which what is known about how people experience new learning environments can be used to create and optimize effective simulation learning environments. When designing and implementing simulation-based learning, extraneous load must be minimized by good design and the intrinsic load must be optimized for the learner. Doing so creates a more effective and valuable learning experience.

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Origins of Cognitive Science and Psychologically Informed Theories of Learning

Cognitive science has long sought to explore the ways in which information is processed by the brain and to generate from this overarching constructs and models of thinking and learning. Indeed, much of what we know about how people learn comes from this background, which traces its roots to the mid-20th century psychologists and their attempts to create a science of learning behavior.

Often, cognitive science theories are contrasted with approaches to learning that tend to look at learning as social, naturalistic, contextual, or experiential phenomena. Indeed, psychological approaches such as cognitive load theory tend to seek to understand the features, scope, limits, and possibilities of the way human beings interact with the world around them when engaging in learning. These approaches often look at learning as a specific and limited phenomenon and seek to understand ways in which information is perceived, processed, stored, and acted on. However, much work in cognitive science over the last two decades has sought to explore learning in much more situated and contextualized environments.

In health professions education, and particularly in health simulation education, there is a paucity of solid theoretical grounding for the design and implementation of learning and teaching (see, e.g., Bligh & Bleakley, 2006; Bradley & Postlethwaite, 2003; Kaakinen & Arwood, 2009). However, an understanding and use of these theories

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can help achieve a more positive learning outcome for learners, make a more robust and educationally sound learning environment, and create a safer health care environment overall (Kneebone, 2005). This article contributes to that aim by exploring cognitive load theory and by articulating how what is known about how people learn can be used to create and optimize effective simulation learning environments. By exploring the background of this theoretical approach, including its roots in psychological studies of information processing and its connections to instructional design, this article argues that salient aspects of cognitive science theory can improve what we do in simulated learning environments that reflect the highly complex world of day-to-day clinical practice.

Key Points

- Cognitive load theory is one of many ways of understanding how people learn and thus should help inform how we design simulation.
- There is a limit to how much information people can process simultaneously, and this impacts how information is stored. Too much information, or too difficult a task, presented in an ill-considered or unstructured way, can result in cognitive overload for a learner.
- The inherent difficulty of a task is considered to be its *intrinsic load*; some of which can be appropriate to the task at hand and thus is referred to as *germane load*.
- The *extraneous load* involves the ways in which the task is presented or designed and can be minimized by instructional design.

Understanding Cognitive Load Theory

Much of the background scholarship and empirical research that informs cognitive load and information processing theory and scholarship developed from the work of behavioral psychologists in the middle of the 20th century. As the science of human behavior came to be an accepted discipline, it was dominated by a positivist research paradigm: experimental research designs, intended to generate knowledge about the ways people interacted with their environment, were predominant. Studies of perception, memory, and information processing from this era shaped and informed much of what we know about the mind today.

Cognitive load theory perceives information processing using formal pathways not unlike that of a computer. Although there are many hypothesized models of information processing, with many nuanced features, they almost all feature a similar basic structure. New information or novel inputs are first dealt with in a working memory. Working memory is optimized for constantly dealing with new information and recalling existing knowledge and for passing it off to other parts of the system as appropriate. However, research seems to indicate that this initial buffer of working memory has very discrete limits on how much information it can handle at one time. Miller (1956) now-famous review of early information processing work argues for the "magical number seven" as the limit on the amount of information that humans can process at any one time. More recent work on information processing has shown variations on this limit but has reinforced the general point that our working memory is limited (Baddeley, 2010).

What working memory is not good at, however, is hanging on to new information for very long; information must be sent to long-term memory for that information to be encoded, indexed, and stored for later use. This process of consolidating new information into long-term memory stores is then aided by a number of factors. These include whether the processing of information is impeded, how much it is rehearsed, and how much someone already knows about the domain in which the information will be situated (Bayliss, Bogdanovs, & Jarrold, 2015). In short, humans are able to maintain and encode slightly more information if we can make sense of it as we take it in; if existing cognitive schema are in place to support the sensory input. Thus, working memory becomes more efficient as domain-specific knowledge increases. For example, letters, over time, become encoded as words, and then as phrases, as our linguistic capacity increases; simple chess moves become complex placements of multiple pieces on a board (Van Merriënboer & Sweller, 2005).

Cognitive load theory seeks to distinguish factors that make this encoding and consolidation of new knowledge more efficient, or conversely, more difficult (Jeroen J. G. Van Merriënboer & Sweller, 2005). Cognitive load theory is particularly helpful when considering how to design learning tasks and environments. At its most basic, cognitive load theory distinguishes between three types of load: (a) intrinsic, (b) extraneous, and (c) germane load (Van Merriënboer, Kester, & Paas, 2006), as shown in Table. The intrinsic load of a learning environment, problem, or task is concerned with its inherent difficulty for a learner and thus is variable depending on a learner's previous experience in a domain. Intrinsic load cannot be lowered, but a learning task can be made more appropriate for the learner's level of expertise or existing knowledge. Extraneous load is entirely related to the presentation of new information or the design of the learning experience: poorly designed learning experiences can be said to have a high extraneous load and thus are not ideal for learning. Germane load is part of the intrinsic load of the task and has to do with making the task appropriately difficult for learners such that the task is challenging and encourages their learning. Too high a cognitive load means that learning cannot happen; therefore, the learning experience or task is not effective. The central