Chapter 7.8
Learners' Cognitive Load When Using Educational Technology

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ABSTRACT

Taking advantage of the rapid evolution of educational technology, simulations and games have been embodied in a variety of teaching and learning procedures. To a large extent, their effectiveness, in common with the effectiveness of all instructional design relies on how material and activities are optimally organized. That organization should be determined by the nature of human cognitive architecture when dealing with complex, biologically secondary information. Cognitive load theory has been devised to deal with such knowledge. Therefore, embodied simulations and serious games should take evidence-based cognitive load principles into account in both design and implementation.

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INTRODUCTION

Games, with features such as voluntariness, fantasy, specific rules/goals, artificial gains/payoffs, competition or cooperation, sensory and motor involvement, challenge, control, low costs of trial and error, and associated amusement (Garris, Ahlers, & Driskell, 2002), might have existed as a type of leisure activity as early as the dawn of civilization, when adults had sufficient food and children were not habitually starving (Dempsey, Haynes, Lucassen, & Casey, 2002). Games not only can be used for recreation but also for educational/training purposes. For instance, in ancient China, individuals learned to play games like Weiqi, or "Go" as it is known in Western countries, to practice various moves in order to become commanders or military strategists. In the modern world, serious, game-based computer systems are widely used for military training as well as for classroom learning (Raybourn, 2007). Currently, learners have an exponentially increasing quantity and variety of educational games available to them (Dipietro, Ferdig, Boyer, & Black, 2007).

During the last two decades, software developers and instructors have introduced a variety of educational games to learners at all levels. According to a recent review of 55 popular educational games and relevant publications/information, 22 games were claimed by their designers to be constructed and developed on the basis of established learning theories or instructional strategies (Kebritchi & Hirumi, 2008). Educational game developers have shown increasing interest in understanding and implementing various pedagogical principles. The pedagogical foundations for some educational games include (a) behaviorist learning theory (e.g., the educational game *Destination Math* uses a stimulus–response model that reinforces desirable learning outcomes during problem solving); (b) experiential learning theory (e.g., students in medical science assume the role of authentic medical practitioners and refer to their authentic experience when playing the *BioHazard* game to deal with simulated medical emergencies); (c) discovery learning theory (e.g., college students are guided to discover a number of basic concepts and underlying processes of market economy by playing *Gamenomics*, which allowed players to explore demands, change purchasing or selling prices, and manipulate supplies and other marketing parameters); (d) situated cognition (e.g., cognitive apprenticeship is employed for teacher education in a classroom management game *simSchool*, which includes a database of realistic student profiles and provides trainees with step-by-step scaffolding, hints, and feedback to acquire essential classroom management skills); and (e) constructivist learning theory (e.g., students learnt electromagnetism by playing *SuperCharged!*, in which they have the discretion to construct their own game level and build up their new knowledge "blocks" toward an optimized level). These examples indicate a growing trend of using extant learning theories and instructional principles in the design and delivery of educational games.

Dempsey and colleagues (2002) attempted to evaluate the features and components of forty computer games that could be used in educational settings. It was found that the most common strategy employed by game players was trial-and-error, even when players were aware of knowledge-based strategies. A trial-and-error strategy, although perhaps being the only option when no knowledge-based strategy is available, can be time-consuming and inefficient. Why do learners not choose a more efficient strategy? Is it because the alternative strategies are not explicitly presented to players/learners during instruction? Or have computer game players become used to the characteristic trial-and-error behavior that has been reinforced by numerous games not equipped with sound instructional principles? In fact, Dempsey and colleagues found game participants complained about poor or no instruction and insufficient feedback. Nevertheless, they did tend to use an "adviser" (i.e., help, hint, and other game tools) and to adopt effective strategies such as mind imagery techniques, memorization, and pattern matching. The study indicated that games designed for educational purposes should not be overly complex, otherwise cognitive overload may occur. Dempsey and associates (2002) further recommend that worked examples (winning prototypes) should be provided to facilitate engagement and learning. The use of worked examples is one of the most effective instructional strategies and is supported by a series of empirical studies in the field of cognitive load theory (Sweller, 2003).

The aims of this chapter are threefold: a) to introduce cognitive load theory in the context of

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