Chapter XLI
Evaluating and Managing Cognitive Load in Games

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ABSTRACT

This chapter provides an overview of our cognitive architecture and its implications for the design of game-based learning environments. Design of educational technologies should take into account how the human mind works and what its cognitive limitations are. Processing limitations of working memory, which becomes overloaded if more than a few chunks of information are processed simultaneously, represent a major factor influencing the effectiveness of learning in educational games. The chapter describes different types and sources of cognitive load and the specific demands of games on cognitive resources. It outlines information presentation design methods for dealing with potential cognitive overload, and presents some techniques (subjective rating scales, dual-task techniques, and concurrent verbal protocols) that could be used for evaluating cognitive load in electronic gaming in education.

INTRODUCTION

The field of gaming and play-based virtual environments as a new educational technology and research area is rapidly expanding (e.g., Gee, 2003; Nelson, Ketelhut, Clarke, Bowman, & Dede, 2005; Shaffer, 2006). If we expect this technology to be efficient in helping students to acquire new, complex knowledge and skills, its design should be based on knowledge of our cognitive architecture and its role in learning and problem solving. Processing limitations of working memory represent a major factor influencing the effectiveness of learning and performance, especially for novice learners. For example, committing limited cognitive resources to processing irrelevant, non-essential, distracting information; on searching for inadequately located references; or on trying to make essential connection between sources of information that are artificially separated in space or time due to poor interface design could substantially slow down learning and performance.

Considering these limitations is particularly important for educational gaming technologies because games usually require simultaneous performances of several cognitive and motor activities. For example, in the game *Peeps,* designed as part of the RAPUNSEL project to teach middle-school girls how to program, players have to navigate the 3D virtual environment, search for objects of value, communicate with other players, avoid *gobblers* who try to steal from them, and collect *peaches* to maintain their energy level (Plass, 2007a). The educational portion of the game, aimed at learning a Java-like programming language in order to design outfits and dances for their avatar, makes additional requirements on the players' cognitive resources. Efficient information designs therefore must focus on substantially reducing cognitive stress in order to enhance learning outcomes.

Levels of learner prior knowledge and experience in a domain represent another important related factor that may significantly influence learning from educational games. Performance and learning characteristics of experienced learners differ considerably from those of novices. Well-organized and often fully or partially automated schematic knowledge structures allow more experienced learners to rapidly recognize and categorize familiar patterns of information without overloading working memory, thus avoiding cognitive stress (Sweller, van Merriënboer, & Paas, 1998; van Merriënboer & Sweller, 2005). The information design in educational games should support the rapid acquisition and use of such knowledge structures by reducing or eliminating unnecessary cognitive overload that may otherwise prevent the allocation of sufficient cognitive resources required for efficient learning and performance.

It should be noted that cognitive load—that is, the demand on cognitive resources during problem solving and reasoning—is always associated with conscious cognitive processes that take place in the learner working memory while performing a current cognitive task. Therefore, the issue of cognitive overload is different from (although it may be related to) problems of general information content overload over longer periods of time or perceptual overload that is traditionally considered in interface design and usability evaluation procedures (e.g., Nielsen, 1995). Cognitive load theory is dealing with factors that influence conscious information processing as we perform a specific task in real time on a scale of seconds or minutes rather than hours or days (in other words, we are dealing with micro- rather than macro-level analysis). Many games have procedures in place that have the potential to overcome high cognitive load for critical tasks, for example, by explicitly providing critical information to solve a task on demand and just in time (Gee, 2003), though the effectiveness of these strategies in reducing cognitive load has not yet been tested empirically.

Evaluation of general usability characteristics of various software applications, including educational games, is traditionally aimed at ensuring that interface components are understandable and recognizable (e.g., have clear meanings and interpretations, employ simple and consistent color-coding schemes, use recognizable and consistent metaphors, use simple and clear language, and provide help if required), and are functionally efficient (e.g., have clear functional roles, provide fast feedback and response times, are easy to recover from errors, and provide clear exit paths) (Nielsen, 2000). Evaluation of cognitive load has not been considered as part of such procedures yet, although there have been some clear indirect indications of possible cognitive overload in the gaming environments. For example, Lim, Nonis, and Hedberg (2006) noted that while being motivating, multi-user virtual gaming environments may also distract from learning because of their high levels of immersiveness and interactivity. In

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