Chapter 7
Utilizing Cognitive Resources in User Interface Designs

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ABSTRACT
This chapter focuses on multiple representations and cognitive perspective about presenting information via different modes in user interface design. Research studies indicate that providing accurate representations increases users’ recognition of information. Moreover, presentation of one concept in multiple modes improves concept acquisition. Developing an understanding of how concept acquisition occurs requires knowledge about cognitive information processing and brain functioning. Scientific studies related to brain functioning will enlighten the path in front of cognitive psychology while the cognitive psychology research will advance the knowledge base on information processing.

INTRODUCTION
Marois (2005) provided a precise example to demonstrate information storage capabilities of human brain: “During our lifetime, our brain will have amassed $10^9$ to $10^{20}$ bits of information, which is more than fifty-thousand times the amount of text contained in the U.S. Library of Congress, or more than five times the amount of the total printed material in the world!” (p. 30). Despite this limitless capacity, we cannot process every piece of information provided to us or store this information in our long-term memory. The reason for not being able to utilize the whole capacity of the brain is still a question to be answered. However, researchers are trying to explain how brain functions physiologically and cognitively to process information. While neuroscientists are trying to answer the puzzling questions about the physiological functioning of brain, cognitive researchers study cognitive information processes. Both types of research provide critical information about human learning processes and in particular the ways of integrating multiple modes into user interface design and the effects of this integration on information processing.

Cognitive psychologists drew attention to limited capacity of human brain and the importance of selective utilization of users’ cognitive resources for effective presentation (Sweller,
van Merrienboer, & Paas, 1998). Foundation for multimodal designs has been set in the cognitive science literature (Mayer, 2005; Revees et al., 2004). Presenting information in multiple modes utilizing users’ cognitive resources effectively is paramount (Baddeley & Hitch, 1974; Clark & Mayer, 2008; Sweller, 1988). If the information about users’ cognitive resources is ignored by designers, representation of a concept in multiple modes may interfere with information acquisition. Overloading working memory or presenting users with redundant information may block the knowledge acquisition either by slowing or stopping the information processing. Thus, developing effective presentation models for users becomes a challenge in user interface design. User interface designers have to take the limitations of working memory into consideration when they design user interfaces. Although current theories and empirical research provide designers some guidelines about how to overcome these limitations, future quality design and development research related to the effectiveness of user interfaces and their development is needed to inform designers further about creation of such environments.

**HOW HUMAN BRAIN FUNCTIONS**

Human brain is the most complicated organ of human body with a myriad of mysteries. Researchers are still trying to figure out how brain functions when it processes information using technological devices such as functional magnetic resonance imaging (fMRI) to measure brain activities during different tasks. One of the critical models developed by neuroscientists about the physiological functioning of brain is the central bottleneck model that analyzes the limitations of human brain in information processing (e.g., Dux, Ivanoff, Asplund, & Marois, 2006; Marois, 2005; Marois & Ivanoff, 2005).

Marois and Ivanoff reported three limitations of working memory derived from the central bottleneck model: (a) visual short-term memory, (b) attentional blink, and (c) psychological refractory period. Human brain can handle a limited number of objects, which is claimed to be four, in the short-term memory simultaneously, and this limitation of brain is referred to as visual short-term memory. Not only the amount of information processed but also the time required for each process is a limitation for the human brain. This processing time is called attentional blink (Marois). Contrary to the misconception that brain is capable of processing information instantaneously, it takes slightly more than a half second for a brain to process the information presented before the brain is disengaged from it to get ready for the next information (Marois & Ivanoff). Human brain processes information in sequential order and needs time before it starts to process the next information in the queue. This lag is called psychological refractory period (Marois). This knowledge base about brain functioning informs the research in cognitive psychology.

Models employed by information-processing theories of learning and memory posit internal structures for human brain: (a) sensory registers, (b) short-term memory (i.e., working memory), and (c) long-term memory. All the information received through senses (i.e., seeing, hearing, and touching) is sent to sensory registers (Ellis & Hunt, 1983). However, only information that catches the human’s attention is transformed into patterns and sent to working memory. This process is called selective perception (Gagne, 1985; Gagne, Briggs, & Wager, 1992). The information selected (attentive selection) in sensory registers by human brain, then, transfers to short-term memory, which is a temporary storage with a limited capacity in terms of the number of items that can be held (Gagne et al.; Marois, 2005). The information in short-term memory is lost unless it is processed or practiced within a short period of time (i.e., 5 to 20 seconds). If the information in working memory is transformed into meaningful form (i.e., semantic encoding), then it can enter
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