Designing Learner-Centered Multimedia Technology

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INTRODUCTION

The ubiquitous use of information technology (IT) promotes a fast-paced and dynamic training environment with enormous potential for performance increases in a variety of domains. This reality has many important ramifications, including how best to incorporate multimedia IT into computer-based training (CBT). Well-designed CBT offers us tremendous potential to effectively and efficiently train the workforce, foster learning in academic environments, and improve performance over and above what is currently achieved. Following a learner-centered design approach, in this article, we present an in-depth look at the use of multimedia CBT, as it relates to aptitude-treatment interactions; that is, how various CBT designs can differentially interact with individual learner aptitudes, such as spatial and verbal ability, to influence training outcomes. The goal of this article is to emphasize the importance of learner-centered design when developing multimedia computer-based instructional material for the growing needs of many sectors of society.

BACKGROUND

CBT has long been touted as a cost-effective and efficient medium for instruction due to, in part, IT availability (e.g., McDermott, 2006). Over the past few decades, a number of theoretical frameworks have flourished, aimed at understanding how multimedia information is processed and how best to design CBT to maximize the amount of information retained from such instruction. For example, Paivio's (e.g., 1971) Dual Coding Theory underscored the importance of using multiple compatible modalities—such as text and images, which are parallel-processed within human working memory—in order to a) generate a strong encoding of processed information, and b) increase memory retrieval of the encoded information when compared to traditional methods employing only one modality (e.g., simply text, narrated lectures, etc.). However, the technological aspect of multimedia training was not yet developed and IT was still in its infancy in relation to CBT. Although IT was not yet widespread, the relevance of Paivio's theory to current CBT design is the focus on the human's capacity for processing multimodal information. Mayer (2001) later espoused this concept in his *Cognitive Theory of Multimedia Learning*, specifically addressing the manner in which CBT multimedia information is processed. Mayer and colleagues devised a number of learner-centered principles guiding CBT instructional design (e.g., Mayer, 1999, 2001) with the goal of helping society capitalize on the ubiquity of IT (e.g., Galvin, 2003; Najar, 1998).

The importance of following learner-centered design principles and guidelines becomes even more paramount for maximizing the potential of IT in a CBT environment. This emerging focus on learner-centered CBT design illustrates a crucial balancing act: on one hand, CBT design needs to capitalize on IT's power and availability; on the other hand, human cognitive limitations need to be considered when developing complex CBT. However, current learner-centered CBT design may be insufficient when individual learner aptitudes come into play. To further improve the efficiency of CBT design, it is pivotal to understand how individual learner characteristics can differentially influence training outcomes (e.g., Mayer, 2001). With this objective in mind, in this article, we present an empirical examination of the interaction between CBT design and individual aptitudes in relation to their impact on the training's learning outcomes and instructional efficiency.

DESIGNING EFFICIENT CBTS: THE MEDIATING ROLE OF INDIVIDUAL APTITUDES

Investigating the influence of specific learner aptitudes, such as spatial and verbal ability, on processing multimedia

information has been an integral component of our research (e.g., Cuevas, Fiore, Bowers, & Salas, 2004; Cuevas, Fiore, & Oser, 2002; Scielzo, Fiore, Dahan, Lopez, & Stafford, 2006; Scielzo, Cuevas, & Fiore, 2005; Scielzo, Fiore, Cuevas, & Klein, 2003). The importance of understanding the complex relationship between individual differences and multimedia information processing offers the opportunity to further refine CBT design guidelines by specifically looking at the manner in which design implementations (treatment) and individual differences (aptitudes) interact. As a result, a more precise learner-centered theory of CBT design can be obtained. Furthermore, evaluating the effectiveness of CBT design requires a number of training outcome measures including (a) assessment of learners' knowledge acquisition, and (b) the instructional efficiency of the CBT program itself, discussed next.

Learner-Centered Computer-Based Training and Assessment

Our approach to assessing learning in CBT utilizes increasingly complex measures of knowledge acquisition—from basic, factual knowledge to more complex integrative knowledge—in order to provide a more complete view of learning as it relates to performance. Our past research investigating CBT design found that the differential effect of training manipulations was often revealed via more complex knowledge assessment measures, that is, only those measures requiring learners to comprehend how various concepts *relate to one another* were able to successfully isolate the effects of training manipulations (e.g., Cuevas et al., 2004; Cuevas et al., 2002; Fiore, Oser, & Cuevas, 2000; Fiore, Cuevas, & Oser, 2003; Fiore, Cuevas, Scielzo, & Salas, 2002; Scielzo et al., 2003).

In addition, instructional efficiency (e.g., Kalyuga, Chandler, & Sweller, 1999; Paas & Van Merrienboer, 1999) has been shown to be an important CBT assessment technique that offers further insight into the effectiveness of varying training manipulations. Instructional efficiency combines standardized measures of knowledge performance and subjective mental workload (perceived cognitive effort during training or performance) to determine overall CBT efficiency; that is, instructional efficiency considers performance levels in relation to the subjective appraisal of how mentally tasking it was to achieve these levels of learning or performance. Specifically, instructional efficiency is a normalized index ranging from -1 to +1, with positive scores indicating higher instructional efficiency (i.e., mental effort exerted is less, relative to the standard effort required to achieve that level of performance) and negative scores indicating lower instructional efficiency (i.e., mental effort exerted is greater, relative to the standard effort required to achieve that level of performance). Baseline (or standard level of efficiency) is represented by zero. Overall, instructional efficiency is an important measure that provides further information to enable instruction system designers to more sensitively distinguish between CBT designs yielding similar levels of performance.

Finally, studies have shown that CBT design manipulations may interact with individual learner aptitudes to influence training outcomes. Aptitude-treatment interactions (see Snow, 1989), in relation to multimedia CBT have been documented to be particularly prominent for spatial (e.g., Chun & Plass, 1997; Mayer, 2001; Scielzo et al., 2006) and verbal (e.g., Cuevas et al., 2002; Chun & Plass, 1997; Mayer, 2001) ability. The next section briefly summarizes empirical findings that more explicitly highlight the mediating role of individual differences on the effect that a given CBT design may have on training outcomes.

Summary of Empirical Findings

Our research on complex multimedia CBT has investigated a number of design manipulations thought to differentially impact training outcomes in terms of knowledge acquisition and instructional efficiency. In our earlier work, individual differences, such as spatial and verbal ability, were covaried out to evaluate the more general effects of design manipulations. For example, when looking at the influence of the differential combination of modalities in a dual-coding paradigm (i.e., presenting one modality vs. two modalities), we found that the beneficial effects of including graphical representations to illustrate concepts presented in text extended to more complex training paradigms requiring the acquisition and integration of numerous concepts over multiple training modules (i.e., training rudimentary aspects of the principles of flight; Fiore et al., 2003). Specifically, results indicated that multimedia CBT combining text and graphical representations supported comprehension and integration in a complex training paradigm. Importantly, by covarying out spatial ability, this effect was isolated using a measure of knowledge integration requiring the ability to understand the relationship of inter-related concepts presented across multiple training modules. These findings, in part, suggest that dual-coding effects (i.e., the claim that encoding instructional material via two modalities improves information retrieval when compared to encoding material via only one modality) do extend to more complex multimedia CBT, but that these effects may only be diagnosable when using measures designed to assess the integration of concepts (Fiore et al., 2003; see also Cuevas et al., 2002).

Expanding upon this line of research, we investigated the effects of differential combination of modalities in a temporal paradigm (i.e., presenting modalities simultaneously or sequentially) and found that the principle of redundancy (Mayer, 2001), indicating that combining narration, text and animations simultaneously is detrimental on knowledge performance due to high levels of workload, did not extend