Computers & Education 58 (2012) 721–731

Contents lists available at SciVerse ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

The effects of presentation method and information density on visual search ability and working memory load

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ARTICLE INFO

Article history:
Received 16 March 2011
Received in revised form
20 August 2011
Accepted 24 September 2011

Keywords:
Computer-mediated communication
Multimedia/hypermedia systems
Human-computer interface

ABSTRACT

This study investigates the effects of successive and simultaneous information presentation methods on learner's visual search ability and working memory load for different information densities. Since the processing of information in the brain depends on the capacity of visual short-term memory (VSTM), the limited information processing capacity of learners may affect the visual search ability and working memory load differently for successive and simultaneous presentations. A change-detection experiment was conducted in this research to analyze visual search ability and working memory load. Two 4×4 dot arrays with three information densities were designed for the two presentation methods to test twenty-two participants. The results of the study indicated significant differences between the visual search abilities and the working memory loads for the two types of presentations at higher levels of information densities. Furthermore, significant differences were identified between visual search abilities for different information densities, due to the limited capacity of VSTM. The correlations of visual search ability and working memory load showed that the attention of the learners with higher visual search ability and lower working memory loads would perform better than the learners with lower visual search ability and higher working memory load.

1. Introduction

With the growth in use of multimedia technology, teachers require access to educational resources in the classroom, to support learners in a variety of ways to meet different learning needs. However, the display space typically available in the classroom is limited to present multiple educational resources. Normally, if different educational resources are presented as shown in the left side of Fig. 1, the related views of multiple resources displayed on a single display may overlap each other. On the other hand, if the multiple resources are used on a single display as shown in the right side of Fig. 1, the content would need to be zoomed to set the simultaneous presentation properly in the single view of the screen. This study focuses on the processing of information presented in different presentation methods and at different levels of information densities through the visual channel in a learner's memory system.

The purpose of this study is to identify how much information an individual processes at the same time when multiple pieces of information are presented on a display and what is the optimal way to present visual information to learners. Learners can constantly process and interact with brief views of visual information; however, their visual search ability and working memory load would be effected by the limited capacity of their visual short-term memory (VSTM) (Huang & Pashler, 2005). Previous studies have reported that only four elements or six spatial locations can be retained in VSTM at a time (Jiang, Olson, & Chun, 2000; Pashler, 1988). Although a number of researchers have conducted psychological experiments to investigate learners' visual search ability through their VSTM, those studies were largely focused on presenting briefly integrated and sequential representations, which had been separated by very short inter-stimuli intervals (Brockmole, Wang, & Irwin, 2002; Jiang & Kumar, 2004; Jiang, Kumar, & Vickery, 2005).

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doi:10.1016/j.compedu.2011.09.022

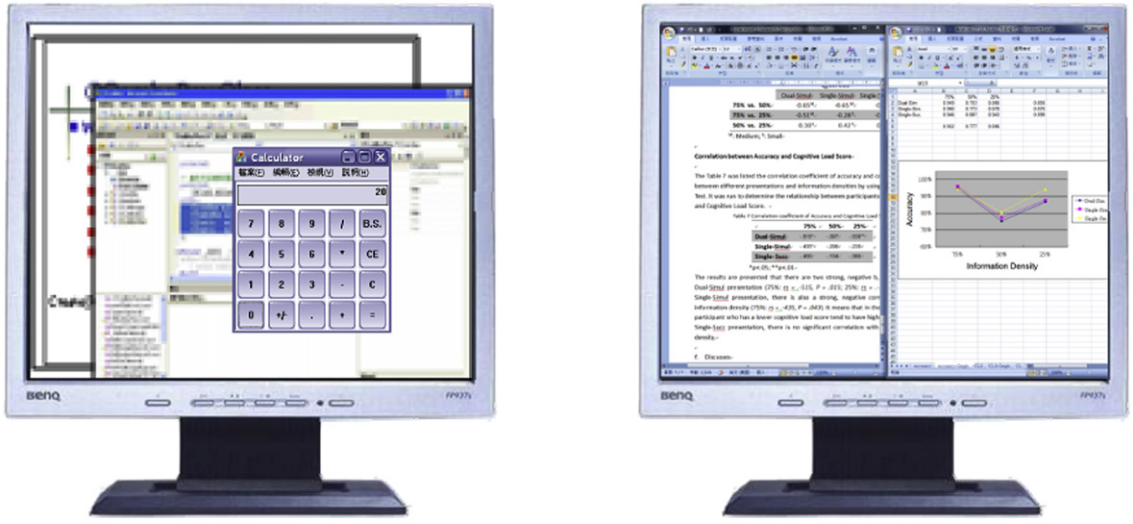

Fig. 1. Multiple educational resources presented on a display: successive presentation (left) and simultaneous presentation (right).

However, limited research is available about the relationship of the capacity of VSTM with displaying different amount of information on a display. Currently, there are mainly two ways to present the information to learners at the same time: successive information where information is presented in a series of sequential multiple images and simultaneous information where multiple views (or images) of information are displayed at the same time. Eriksen and Spencer (1969) first introduced the method of successive/simultaneous comparison for testing information processing capacity in visual perception. Perrin (1969) pointed that learners make better related connections with simultaneous images than with successive images. He also argued that the density of information presented at the same time will affect the ability of a learner's individual cognitive processes in visual short-term memory system. However, when multiple images are presented on one single display, the density of presented information is increased. Accordingly, this study attempts to analyze the effects of information densities within the simultaneous and successive presentations on a display. In order to analyze the correlations between visual search ability and working memory load, a change-detection experiment is used to measure visual search ability of detecting the differences between multiple images and working memory load of processing different presentations with different levels of information densities. The measured visual search ability represents the ability of visual short-term memory for searching the visual information; and the measured working memory load represents the overload of learners' VSTM during processing different presentations from their cognitive perspective.

In this study, several research questions related to the relationships of the visual search ability and working memory load in learners' information processing system are analyzed. The first aim of the study is to find out whether the visual search ability of learners is significantly affected by presenting same information on any of the two kinds of presentation methods: simultaneous presentation of information on the display (all information available at the same time) and successive presentation of that same information on the display (not all information available at the same time). Second, this study aims to find out whether different information density levels have any significant influence on the visual search ability of the learners. Three different levels of information densities are used in this study, namely higher (75%), medium (50%), or lower (25%) density of information. Perrin (1969) noted that information density is a critical factor for making contrasts and comparisons, and for finding relevant information between multiple educational recourses. The ability of detecting the differences between different types of information is represented by the visual search ability (Huang & Pashler, 2005; Jiang & Kumar, 2004; Jiang et al., 2005; Wilken & Ma, 2004). Third, this study aims to analyze the effects of working memory load on processing different types of information, in order to figure out whether the working memory load of learners differs significantly when the information is presented through the two kinds of presentation methods. Fourth, this study also attempts to figure out whether there is a significant difference in learners' working memory load when information is presented with three levels of information densities. The working memory load for each presentation method and each information density in this study is represented by the amount of working memory load while self-searching and detection tasks were performed concurrently (Brünken, Plass, & Leutner, 2003; Woodman & Luck, 2004). Finally, on the basis of the findings from the above research questions, this study aims to find the correlations between visual search ability and working memory load in simultaneous and successive presentation methods with three levels of information densities.

2. Background

2.1. Information processing in human memory system

The human memory system works similar to an information processing system and operates like an advanced computer system as shown in Fig. 2 (Atkinson & Shiffrin, 1968). There are three types of memory: sensory memory, short-term memory, and long-term memory. The sensory memory acts as a buffer for receiving the input information (stimuli) through the senses or channels (i.e. eyes and ears). Information is passed from sensory memory (visual or verbal channel) into short-term memory by attention. In short-term memory, the ability of processing information may be affected by the amount of attention devoted to the task of encoding the information. The short-term memory then processes the information either to store it into the long-term memory by rehearsing the information repeatedly or