Surgical Multimedia Academic, Research and Training (S.M.A.R.T.) Tool: A Comparative Analysis of Cognitive Efficiency for Two Multimedia Learning Interfaces that Teach the Pre-procedural Processes for Carpal Tunnel Release

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Abstract: This study proposes a series of guidelines for designing multimedia educational interfaces that combine educational strategies with cognitive load theory. There is a large body of research that confirms multimedia education is at least as effective as the traditional approach, but there is no discussion regarding the effectiveness of the interface design. This trial compares two interfaces to determine which design techniques are most cognitively efficient for the learner.

Keywords: Cognitive process, multimedia learning, interface design

1. Introduction

Multimedia instruction has provided a sophisticated method whereby traditional text and illustrations can be incorporated into interactive, multi-dimensional software. A presentation using text, illustrations, animations and video can assist the learner in building a mental model of the material. Students who receive well-constructed multimedia messages perform better on transfer tests designed to measure overall comprehension and problem solving ability, than do students who receive messages through traditional didactic method [1]. The authors assert that students learning through advanced multimedia interfaces that account for theories of cognitive load will achieve better comprehension of given lesson as compared to interfaces that do not.

As technologies become integrated at all educational levels, it is necessary to establish what design techniques are most successful in creating multimedia learning tools. Despite enthusiasm for incorporating multimedia, the assumption that interactive media alone will advance learning is simplistic. Merely translating a preexisting
curriculum to a multimedia format is insufficient; rather, new curriculums and lesson plans must be designed for multimedia environments. This experiment serves to quantify the efficacy of trends in multimedia education and offers design guidelines that address the cognitive properties utilized in the learning process.

2. Background

This experiment utilizes a literature review conducted by Grunwald and Corsbie-Massay entitled “Guidelines for Cognitively Efficient Multimedia Learning Tools: A review of literature relating to educational strategies, cognitive load and interface design”[2]. This review combines existing educational strategies and cognitive load theory to propose a series of guidelines for designing a cognitively efficient multimedia interface.

When developing a multimedia learning tool (MML), it is necessary to distinguish between media, which delivers the message, and the symbolic systems used to convey the message [3]. Many quantitative studies neglect to make this distinction thereby confusing the source of changes in learning. According to Mayer, “it is not possible to separate the effects of the medium from the effects of instructional method... learning outcomes depend on the quality of the instructional method rather than on the medium per se” [4]. In other words, learning is influenced by instructional methods, not the media by which it is delivered [2]. Therefore, a successful education strategy, one that assists students in retaining information in their long-term memory despite a limited working memory, must be developed before designing an MML. The following guidelines help create active learners and encourage long-term retention of newly acquired knowledge.

1. Create active, self-directed learners
2. Involve student in goal planning and agenda development
3. Maintain authentic context
4. Provide student sensitive instructional feedback
5. Provide student sensitive environment
6. Reflect on learning goals

Cognitive load theory is based on information processing assumptions, including Mayer’s ‘dual channel assumption,’ which states that humans possess separate information processing channels for visual and auditory material (text information is interpreted through the auditory pathway), and the ‘limited capacity assumption,’ which limits the amount of information can that be consumed by either channel at one time (See Figure 1) [4]. Combined, the human working memory is capable of holding an average of seven items at once [5]. The number of elements that are consciously or unconsciously attended to by the learner is necessary in calculating the total cognitive load of an interface. The student must integrate the discreet bundles of information into a limitless long-term memory and the expanse of this long-term memory determines his or her proficiency with a given subject [2]. The following guidelines assist in creating an interface that reduces cognitive load.

1. Synchronize audio and visual information
2. Eliminate multi-tasking
3. Optimize representations/Approachable interface
4. Maintain stable learning environment
5. Eliminate redundant information
6. Manage navigational control
7. Maintain authentic context

The currently available research is lacking in studies specifically regarding the supplemental features of an MML such as a glossary and image control functions. Statistics regarding additional learning resources including the electronic notebook, lecture/surgery notes or Frequently Asked Questions (FAQs) are scarce. Bauml et al. [6] conducted trials of EMCyberSchool that featured a supplementary online program with an extended resource of additional cases and images. The program proved successful without addressing the role of the additional resources in this success. Although additional materials are considered essential to learning, their usage rates are not addressed. Medical MML developers assume that more is better, but without strong evidence as to their utility and efficacy, money, time and effort may be wasted. Further research is necessary to discover what groups of learners benefit most from which resources.

The S.M.A.R.T. Tool seeks to discover the best synchronization of audio-visual information while documenting the learner’s use of various learning resources to quantify when and how they are utilized. The experiment also tallies the student’s interaction with the provided images.

![Image of Dual Channel Assumption](image.png)

**Figure 1.** Dual Channel Assumption [4]

3. **Study Design**

This study is a randomized controlled trial that quantitatively assesses the efficiency of different interface designs. Two dynamic interfaces were designed specifically for this study. Both teach the preliminary processes of carpal tunnel release, but vary in presentation to cater to the students’ cognitive and educational needs.

3.1 **Subjects**

Our subjects include 80 medical students from the USC Keck Medical School. Subjects are randomly assigned to either interface A or interface B; each subject interacts with the program for a maximum of 15 minutes, followed by a cognitive assessment to determine the educational efficiency of each interface. Subjects were observed to discover how they interact with the interface and what learning resources
they choose to utilize. By observing the student’s interaction with the program, we hope to distinguish what resources are beneficial.

3.2 Program Development

This experiment utilizes a custom designed Flash MX program that teaches basic surgical and procedural concepts for carpal tunnel release. This dynamic program provides text images and audio to create an immersive media environment for the learner. The monitor is divided into two windows, a text window and an image window (see Figure 2). The text script was taken from an available teaching module for carpal tunnel syndrome. The image window plays a simple movie during the audio presentation after which the user is free to interact with highlighted text. These links control the image window and/or provide additional information. The program offers a variety of optional learning resources to assist the student including a hyperlinked glossary and expandable images.

The control interface (A) provides a simplistic multimedia interpretation of the material, similar to that of an existing multimedia textbook: the audio script is presented in the text window. The experimental interface (B) rephrases the visual delivery of the text; key terms and phrases are reorganized into an outline format that is revealed line by line in sync with the audio presentation.

The experimental interface is designed to test two design guidelines provided in the authors’ aforementioned review: the appropriate presentation of audio and visual information and eliminating redundant material. The outline format visually reinforces the information provided in the audio channel and reduces redundant information, thereby utilizing the dual channel pathway to maximize the number of distinct items retained in the working memory. By revealing each line in conjunction with its audio reading, small chunks of information are presented simultaneously; each complement the others within the short-term working memory to better integrate into long-term memory.

![Figure 2: S.M.A.R.T. Tool, control and experimental interfaces](image-url)
4. **Discussion**

The ultimate goal of the S.M.A.R.T. Project is to design a fully comprehensive multimedia educational environment that can reduce the time necessary to acquire and perfect a skill as well as the monetary and temporal demands on the teaching hospital and its faculty. Our intention is not eliminate teaching in the operating room; rather, we are working specifically with fundamental surgical skills and decision making to allow for advanced teaching in the operating room.

This experiment will discover the best interface design for disseminating information regardless of the lesson or the field of inquiry. It will provide statistical data to confirm what presentation is most cognitively efficient for the user as well as an investigation into the learner’s use of various learning resources. During testing, subjects were observed to discover the time spent with each module and how learning resources were utilized.

Although several MMLs provide supplemental glossaries and other learning resources, their efficacy is not quantified, rather the learning resources are assumed to enhance the MML without accounting for how they are used. By correlating performance on assessment tools with the time spent within each learning module and the student’s interaction with the available supplemental image, the authors will present the best method of integrating various learning resources.

Existing multimedia learning tools fail to address cognitive load when anticipating the learner’s interaction with the program. This study investigates MMLs that account for cognitive load and compares them with available learning tools. We will discuss a series of guidelines that can be employed by designers of medical education software as well as areas for future research.

**References**


