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Understanding Effective Use of Rich Media in Instructional Design

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Abstract

When it comes to the development of instructional technology "multimedia has been developed on the basis of its technological capacity, and rarely is it used according to research based principles" (Moreno & Mayer, 1999). To be an effective instructional designer, ID specialists must be aware of the research that has been done concerning the effects rich media has on a learner's cognitive load. They must understand that learners entering into a learning environment are extremely diverse in their existing knowledge base. In order for the appropriate instruction to be applied to each individual learner, a learner's existing knowledge base must be identified in order to avoid applying instruction which might cause cognitive load problems and thereby reduce the effectiveness of the instruction itself. Taking into account research on spatial-contiguity effect, temporal-contiguity effect, the modality effect, the expertise reversal effect, and the redundancy effect, is an important part of being a successful modern-day instructional designer. Now more than ever, in order for instructional designers to be able to optimize their instructional designs they need to be cognizant of all the variables that can result in either a positive or negative impact on a learner's cognitive load in order to produce effective learning environments. An analysis of published research articles on the positive and negative effects of rich media on cognitive load and how best to determine a learner's existing knowledge base regarding a particular subject matter are the subjects of this paper.

Introduction

When it comes to the design of learning environments, The National Research Council frames the discussion this way, "[l]earning theory does not provide a simple recipe for designing effective learning environments; similarly, physics constrains but does not dictate how to build a bridge" (2000). Historically, in the development of instructional technology, "multimedia has been developed on the basis of its technological capacity, and rarely is it used according to research based principles" (Moreno & Mayer, 1999). To be an effective instructional designer, ID specialists must be aware of the research that has been done concerning the effects rich media has on a learner's cognitive load. They must understand that learners entering into a learning environment are extremely diverse in their existing knowledge base. In order for the appropriate instruction to be applied to each individual learner, a learner's existing knowledge base must be identified in order to avoid applying instruction which might cause cognitive load problems and thereby reduce the effectiveness of the instruction itself. Taking into account research on spatial-contiguity effect, temporal-contiguity effect, the modality effect, the expertise reversal effect, and the redundancy effect, is an important part of being a successful modern-day instructional designer. Now more than ever, in order for instructional designers to be able to optimize their instructional designs they need to be cognizant of all the variables that can result in either a positive or negative impact on a learner's cognitive load in order to produce effective learning environments. An analysis of published research articles on the positive and negative effects of rich media on cognitive load and how best to determine a learner's existing knowledge base regarding a particular subject matter are the subjects of this essay.

Cognitive Load Theories

Many cognitive learning theories began their rise to prominence if the 1970's (Reiser & Dempsey, 2007). Among the more popular of these theories is the Cognitive Load theory. With recent advances in neurobiology, like PET scans and fMRIs, there has been increasing evidence for the validity of many cognitive load theories (Merriam, Caffarella, & Baumgartner, 2007) (Dual-coding Theory, 2009). For designers of interactive multimedia, one important cognitive load principle to keep in mind is that of dual coding theory (DCT). A theory first brought to light by James. M. Clark and Allan Paivio in their September 1991 article published in *Educational Psychology Review*, which as Alessi and Trollip put it "suggests that learning is enhanced when complementary information codes are received simultaneously" (2001). Although there had been some research written about dual coding by Yates (1966) and Rossi as early as the 1960s, the Clark/Paivio article is considered to be the seminal paper on the subject.

Mayer and Moreno Studies

Additional and more recent research on DCT has been conducted by Richard E. Mayer and Roxana Moreno, professors at the University of California, Santa Barbara and the University of New Mexico, Albuquerque, respectively. Mayer has authored several books focusing on the effects of rich media in learning including: *Multimedia Learning, 2nd Ed., e-Learning and the Science of Instruction: Proven Guidelines for consumers and Designers of Multimedia Learning,* and most recently, *Applying the Science of Learning*. Mayer and Moreno together have conducted numerous amounts of research in the area of cognitive load theories and how they relate to the human learning process. In 1999 they published the results of one such study in an article titled *Cognitive Principles of Multimedia Learning: The Role of Modality and Contiguity*.

The purpose of their research was to examine the effects of verbal presentation modes compared with non-verbal presentation modes in multimedia learning. In their first experiment they focused on spatial contiguity, studying how the location of on-screen text affects learning. The study was conducted using 132 college students, deemed to have little knowledge of meteorology, divided into three groups identified as N, IT, and ST. All participants were provided with a pencil, a questionnaire, a retention test, a matching test, and a 4-page transfer test to record each participant's meteorological knowledge going into the experiment. The instruction consisted of a multimedia presentation on how lightning works. The same animations were shown to all participants. The N group's presentation included narration of the subject matter. The ST group's presentation consisted of concurrently displayed text which was located at the bottom of the screen, under the animation being presented. The IT group's presentation consisted of concurrently displayed text that was integrated into the animation in a "physically close proximity to the relevant part of the animation" (Moreno & Mayer, 1999). After viewing the animation each group was asked to complete a retention test, a problem-solving test, and a matching test in a timed format. In this experiment the independent variable was the verbal modality each participant received while viewing the instructional animation on lightning. The dependent variable was how well each participant scored on the three post tests measuring verbal recall, retention, matching, and transfer. An analysis of variance (ANOVA) was applied to the data collected with the results being what the researchers expected. The narration (N) group scored considerably higher (13% to 20%) than the other two groups in the verbal recall, transfer, and matching tests, with the integrated text (IT) group outscoring the separated text (ST) group on all three tests as well (about 8% on average).

Because the results of their first experiment could be interpreted in two ways, a) it could be that working memory capacity is better when both audio and visual information is presented simultaneously (modality) or b) it could be that using on-screen text in addition to the animation is preventing the viewer from attending to each piece of information quickly enough (contiguity). Mayer and Moore developed a second experiment to distinguish between modality and contiguity. Participants for the second experiment were gathered and evaluated in similar fashion to the first group of participants, this time however they were divided into six separate groups. Groups NN would view the animation as did group N in the first experiment using narration as the verbal delivery method and group TT would view the same presentation as the ST group previously. The new groups NA, AN, TA, and AT would respectively, hear the narration first and then view the animation, view the animation first and then hear the narration, read the verbal text first and then view the animation, and view the animation first and then read the verbal text afterwards. Again the independent variable was how each group was being presented the animated and verbal instruction, the dependent variable was how well they scored on the verbal recall, transfer, and matching tests taken after the instructional presentations, and the collected test scores were analyzed using ANOVA. Those receiving the narrated verbal presentations, groups NN, AN, and NA outperformed the other three, verbal text only groups, with the exception of the matching test; however, the NA group scored slightly higher than the AN and NN groups in verbal recall, with the AN group equaling the NN group for top honors on the transfer test, and group AN barely outperformed groups NN and NA, who had equal performance, on the matching test. The anomaly, when compared to previous research was that with the exception of the TT group the other verbal text groups TA and AT were close in scores to the narration groups for the matching test. Both of these experiments “contributes to multimedia learning theory by clarifying and testing two cognitive principals: the contiguity principle and the modality principle" (Moreno & Mayer, 1999).

Kaluga and Sweller Studies

Kaluga and Sweller, cite the expertise reversal (Kalyuga, Ayres, Chandler, & Sweller, 2003) and the redundancy effect (Bobis, Sweller, & Cooper, 1993) as the reasoning behind why they developed and published their research titled *Measuring Knowledge to Optimize Cognitive Load Factors During Instruction* in 2004. In their article they state that "instructional designs should be based on user-adapted instructional procedures by matching instructional presentations to levels of learner knowledge in a specific task domain" (Kalyuga & Sweller, 2004). To that end Kalyuga and Sweller developed 4 experiments which would 1) "investigate if a rapid test of learner knowledge in a domain based on a schema theory view of knowledge held in long-term memory could be validated by correlating highly with a multilevel traditional test of knowledge" (Kalyuga & Sweller, 2004), 2) replicate the results of the first experiment using a different schema, 3) "evaluate the ability of the rapid testing procedure to detect … an interaction between levels of learners' knowledge in a domain and levels of instructional guidance (expert reversal effect)" (S. Kalyuga & Sweller, 2004), and 4) "see if the rapid test could be effectively used in a computer-based training environment for adapting instructional procedures to changing levels of learner's knowledge domain" (Kalyuga & Sweller, 2004).

The first experiment was conducted in a realistic class room environment and consisted of two tests. The first test was a traditional test in which learners where asked to solve 12 algebraic equations as completely and accurately as possible. The second test also consisted of 12 algebraic equations, but this time each equation was presented in varying solution stages and learners were asked to only come up with the next step in the solution of the equation. The independent variable in this case was the format of the test and the type of answer each student was asked to give, the complete solution versus only having to provide the next step in solving an equation. The dependent variables were time and accuracy of the student answers. The researchers stated that the test administration had not been counterbalanced as it would have "eliminated practice effects but caused misinterpretations of correlations between performance scores in the two conditions, which was the main goal of this experiment" (Kalyuga & Sweller, 2004). After analyzing the results of their experiment, Kalyuga and Sweller found "a highly significant correlation between learners' performance on the rapid test tasks and traditional measures of learners' knowledge" (2004).

The second experiment, as stated earlier, was used only to confirm the results of the first and the only difference was that a different knowledge domain was used in the testing process, geometry problems instead of algebraic problems. The results of the second experiment confirmed the results of the first, that the rapid testing procedure accurately represented learner knowledge.

In the third experiment an attempt was made to see if the rapid testing procedure could be used to replicate the expert reversal effect that had been observed in other experiments where traditional testing was used. After first applying the rapid testing method used in the first two experiments to the participants of the third experiment, the participants were divided into two groups: more knowledgeable and less knowledgeable. Next, each group of participants were divided in half and given two different methods of instruction, worked-examples-based instruction and problem-solving-based instruction. The independent variables in this experiment were the levels of participant knowledge (high/low) and the format of instruction (worked-examples/problem-solving). The Dependent variable was post-instruction performance. In order to evaluate the results a 2 X 2 ANOVA was applied to the resultant data set of experiment 3. As would be expected, the high knowledge learners outperformed the lower knowledge learners, but the interesting result derived from this experiment was that there was little difference in the test results of the high knowledge learners regardless of the instructional method applied. Whereas, there was a significant amount of difference amongst the low knowledge group that directly correlated with the instructional method applied. Those that were given the worked-examples instruction scored considerably higher than those who learned from the problem-solving instruction. Researchers attribute the observed learning differences between the high knowledge learners and the low knowledge learners to the expertise reversal effect. The expertise reversal effect is a cognitive learning theory which says that learners who have more knowledge (expertise) in a domain benefit less from overly detailed instruction than do learners who initially posses less domain specific knowledge.

Kaluga and Sweller's final experiment in this project was designed "to see if the rapid test could be effectively used in a computer-based training environment for adapting instructional procedures to changing levels of learners' knowledge in a domain" (Kalyuga & Sweller, 2004). *Figure 1* (below) shows a flowchart depicting the methodology used by the researchers to determine learners' existing knowledge level and how it was used to apply training appropriate to that knowledge level. This methodology was applied to the control group whereas a group of non-adapted learners' were sequenced through the worked examples training and rapid testing without regard to their knowledge of the information being presented and tested. For this

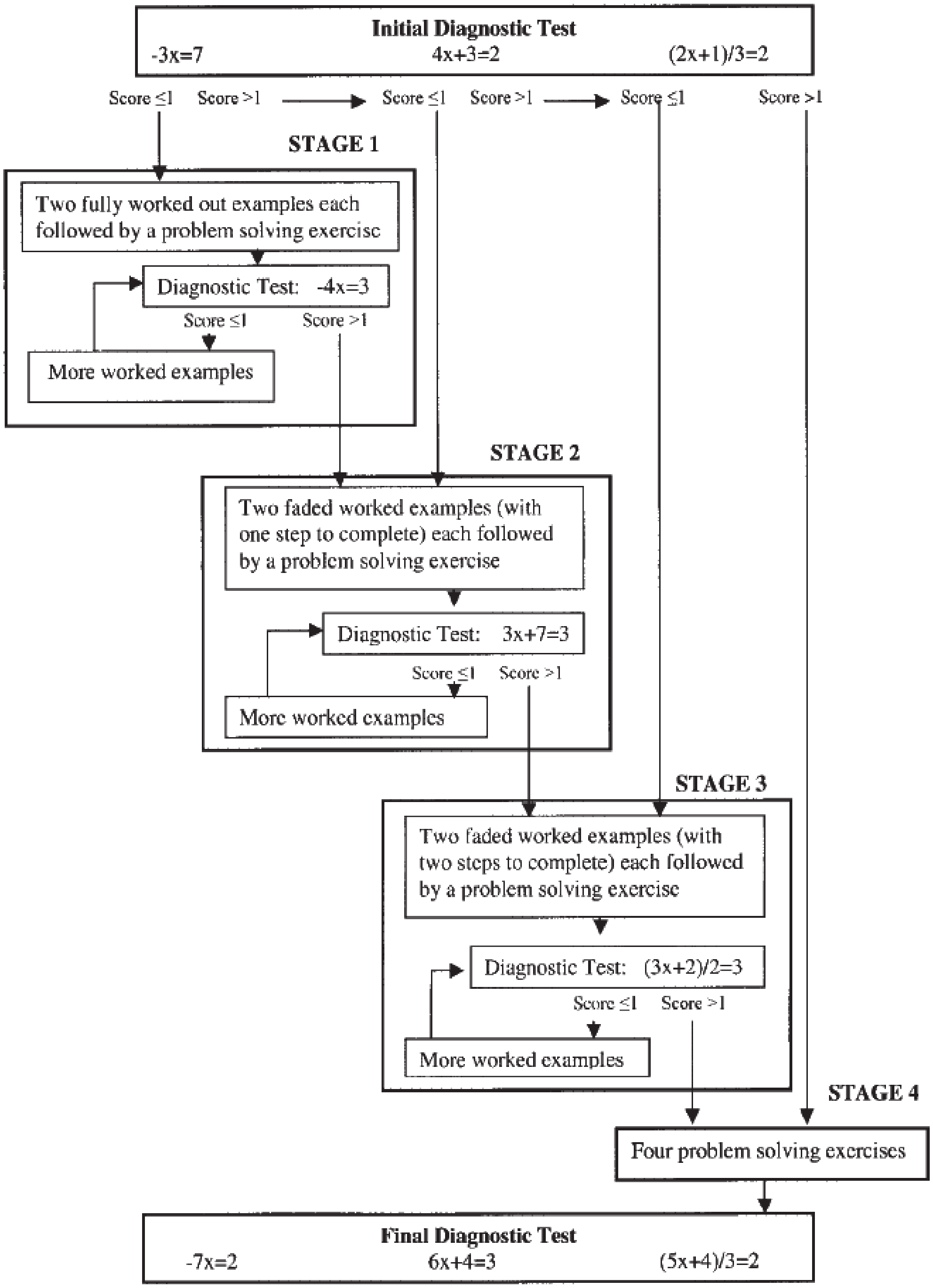

Figure 1 Flowchart used by Kalyuga & Sweller to show the adaptive procedure for their experimental training session.
Source: Reprinted from *Measuring Knowledge to Optimize Cognitive Load Factors During Instruction* (figure 2) by Kalyuga & Sweller 2004.

experiment the independent variable was the "format of the training session (learner adapted or randomly assigned)" (S. Kalyuga & Sweller, 2004) and the dependent variables were the “differences between the sum of the three test scores for the final rapid test and the sum of the three test scores for the initial rapid test” (S. Kalyuga & Sweller, 2004). Due to the higher knowledge gains achieved by the learner-adapted group when compared to the randomly assigned format group, Kalyuga and Sweller state that there is “strong evidence that the suggested rapid measure of expertise, based on knowledge of human cognitive processes, can be successfully used to enhance learning outcome by adapting instruction to learners’ knowledge levels based on the expertise reversal effect” (S. Kalyuga & Sweller, 2004).

Conclusion

It has been too often the case that instructional designers choose to use rich media components in instruction without regard to their actual impact on learning outcomes. This research by Clark, Kalyuga, Mayer, Moreno, Paivio, and Sweller as well as other cognitive load researchers makes the case for the necessity of Instructional Designers to be aware of and to aptly apply, theories that have been developed in the area of cognitive load as it relates to rich media inclusion into instructional methods. Morena and Mayer have introduced theories on modality, and spatial and temporal congruity, Kalyuga and Sweller’s study brought an awareness of the need for prior analysis of learners’ knowledge levels to prevent the expert reversal effect, and that adaptation of learning methods can be applied to achieve successful learning outcomes. Now more than ever, it is extremely important that ID specialists study research of this nature to become better informed and more proficient instructional designers, for the sake of the learners to which they affect.

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