Getting the Message Across: The Role of Verbal Redundancy in Multimedia Explanations

Roxana Moreno
University of New Mexico
Richard E. Mayer
University of California, Santa Barbara

Roxana Moreno
College of Education
University of New Mexico
Albuquerque, NM 87131
moreno@unm.edu

Objectives and Theoretical Framework

Past research in multimedia learning has demonstrated a modality effect according to which students who study from pictures and spoken words outperform students who study the same pictures with text (Moreno & Mayer, 1999a). This was the case of the studies conducted by Mousavi, Low, and Sweller (1995) involving the presentation of geometry worked examples, Mayer and Moreno (1998) involving the presentation of simultaneous animations and explanations about a scientific system, and Moreno and Mayer (1999a), involving the presentation of sequential animations and explanations about a scientific system. In all studies, students learned more effectively when the visual materials were accompanied by speech rather than by text.

The beneficial effects of auditory messages in multimedia has been interpreted as a result of the expanded effective working memory capacity that occurs when auditory working memory is used to process words and visual working memory is used to process pictures (Penney, 1989; Moreno & Mayer, 1999a). However, the following question still remains: Would verbally redundant messages, that is, messages presented via speech and text, enhance students' understanding even further? In order to answer this question, we conducted a set of three studies where students were presented with an explanation about the process of lightning formation. In all studies we compared the learning outcomes of students who learned with a narrated explanation to those of students who learned with an identical narration plus on-screen text. Learning was measured by retention, transfer, and matching tests. The role of verbal redundancy was investigated for the case of a multimedia explanation that included sequential animations (Experiment 1), environmental sounds (Experiment 2), and simultaneous animations (Experiment 3).

Predictions from a Cognitive Theory of Multimedia Learning

In the past, bimodal word processing and bimodal reading have been found to increase memory for words and comprehension of text (Lewandowski & Kobus, 1993; Montali & Lewandowski, 1996; Penney, 1989). On the other hand, negative verbal redundancy effects have been found using static diagrams and printed text (Kalyuga, Chandler, & Sweller, 1998, 1999). The studies conducted by Kalyuga et al. (1998, 1999) show that people who learn from diagrams and speech perform better on subsequent cognitive tasks than people who receive diagrams along with both speech and text. The goal of the present study is to test a dual-processing model of multimedia learning that would reconcile the discrepancy between the seemingly opposing findings of past research on redundancy effects.

Our research draws on several theoretical frameworks: first, dual-processing theory--the idea that humans have separate verbal and non-verbal information processing systems (Clark & Paivio, 1991; Paivio, 1986); second, cognitive-load theory--the idea that the capacity of the visual and auditory working memory systems is limited (Baddeley, 1992; Chandler & Sweller, 1991); and third, generative-learning theory--the idea that meaningful learning involves selecting relevant verbal and non-verbal information, organizing it into coherent representations, and making connections between representations and with prior knowledge (Mayer, 1996; Moreno & Mayer, 1999a)

According to dual-processing theory, by reading text with concurrent narration, students represent the text in visual working memory and represent the corresponding narration in auditory working memory. Because the auditory and visual processing channels are independent (Penney, 1989), students can hold both representations in working memory at the same time and build referential connections between them (Mayer & Moreno, 1998; Moreno & Mayer, 1999a; 1999b).

However, for some multimedia designs, verbal redundancy may cause students' limited working memory capacity to become overburdened. For example, when students are presented with a concurrent animation, they try to represent both the animation and the on-screen text in visual working memory. Given the limited resources students have for visual information processing, using a visual modality to present both pictorial and verbal information can create an overload situation for the learner (Mayer & Moreno, 1998; Moreno & Mayer, 1999a; 1999b). This is not the case for sequential presentations, where the animation and text are not presented simultaneously thus do not compete for visual working memory resources (Moreno & Mayer, 1999). Similarly, for messages that include environmental sounds, students need to hold the auditory verbal and non-verbal sources of information in their auditory working memory

(Moreno & Mayer, 2000). Although the auditory channel is limited in capacity (Baddeley, 1992), the processing of words and sounds can be represented in separate verbal and non-verbal systems and linked to each other in an associative network (Paivio, 1986; Clark & Paivio, 1991). Unlike the case for text and animation in the visual channel, attending to the spoken words does not prevent listening to background sounds and vice-versa (Moreno & Mayer, 2000). Therefore, our theory predicts that students' learning from redundant explanations will not be hurt but rather enhanced under conditions of sequential animations or presentations that include relevant sounds.

Methods and Data Source

In three studies, we compared the learning outcomes of students who received a redundant multimedia explanation (via narration and text) with those who received a non-redundant explanation (via narration alone) about the process of lightning formation. All participants had indicated that they lacked experience in meteorology. In Experiment 1, 19 students listened to a narrated explanation (Group N), 19 listened to a narrated explanation accompanied by text (Group NT), 18 were presented with a cycle of a depictive animation followed by a corresponding cycle of the narration (Group A-N), and 18 were presented with cycles of the animation followed by a corresponding cycle of narration and text (Group A-NT). Similar to Experiment 1, in Experiment 2, 17 students served in Group N and 18 participants served in Group NT. In addition, 17 students were presented with narration and environmental sounds (Group NS), and 19 were presented with narration, text, and environmental sounds (Group NST). In Experiment 3, 18 participants served in the A-NT group and 17 served in the A-N group similar to Experiment 1. Additionally, 18 students were presented with simultaneous animation, narration and text (Group ANT) and 16 students were presented with simultaneous animation and narration (Group AN).

Participants were tested in groups of 1 to 5 per session. For each study, the participants were randomly assigned to a treatment group and seated at an individual cubicle in front of a computer. First, students were given a questionnaire, which solicited demographic information. Second, the respective version of the multimedia program was presented. After the presentation was over, participants were tested on retention, transfer, and matching of the visual and verbal materials from the lesson. The retention test asked students to write an explanation of how lightning works. After 5 minutes, a set of problem-solving transfer questions (such as, "What can be done to reduce the intensity of a lightning storm?) were presented one at a time for 3 minutes each. Finally, students were given a matching test in which they had to circle and label designated elements in a graphic representing the lightning system.

Results

For each of the three dependent measures (i.e., retention, transfer, and matching) the data were subjected to a two-way analysis of variance with the between subjects factors being verbal redundancy and presence or absence of animation (Experiment 1), sounds (Experiment 2) or presentation order (Experiment 3).

For Experiments 1 and 2, the two-way ANOVA revealed that students remembered significantly more when the verbal material was redundant ($M = 9.70$, $SD = 4.03$ and $M = 8.76$, $SD = 2.86$, respectively) than when it was not ($M = 6.92$, $SD = 3.57$ and $M = 4.03$, $SD = 2.48$, respectively), $F(1, 70) = 12.18$, $MSE = 143.09$, $p = .0008$ and $F(1, 67) = 53.64$, $MSE = 395.43$, $p = .0001$, respectively; generated significantly more conceptual creative solutions on the transfer test when the verbal material was redundant ($M = 2.81$, $SD = 1.39$ and $M = 2.95$, $SD = 1.49$, respectively) than when it was not ($M = 1.11$, $SD = 1.05$ and $M = .68$, $SD = .73$, respectively), $F(1, 70) = 36.56$, $MSE = 53.81$, $p = .0001$ and $F(1, 67) = 62.96$, $MSE = 91.11$, $p = .0001$, respectively; and correctly matched more items when the verbal material was redundant ($M = 6.49$, $SD = 1.74$ and $M = 5.89$, $SD = 1.63$, respectively) than when it was not ($M = 5.70$, $SD = 2.01$ and $M = 4.41$, $SD = 2.18$, respectively), $F(1, 70) = 3.82$, $MSE = 11.02$, $p = .05$ and $F(1, 67) = 10.20$, $MSE = 37.73$, $p < .005$, respectively.

Experiment 3 failed to reveal that students remembered significantly more, generated significantly more conceptual creative solutions, or correctly matched more items when the verbal material was redundant than when it was not. However, a significant interaction between redundancy and presentation order for the retention and transfer scores was found, $F(1, 65) = 9.62$, $MSE = 77.31$, $p < .005$, and $F(1, 65) = 7.05$, $MSE = 9.60$, $p = .05$, respectively. Consistent with the predictions of a dual-processing theory of multimedia learning, for simultaneous presentations, a split-attention effect between the on-screen text and the animation occurs and the redundant messages hurt rather than help students' learning (for retention, $M = 8.28$, $SD = 2.08$ and $M = 11.06$, $SD = 2.62$, and for transfer, $M = 1.28$, $SD = 1.13$ and $M = 2.06$, $SD = 1.06$ for groups ANT and AN, respectively). Conversely, students presented with redundant verbal materials outperformed students who learned with non-redundant verbal materials for the sequential presentations (for retention, $M = 10.28$, $SD = 3.32$ and $M = 8.82$, $SD = 3.15$, and for transfer, $M = 2.94$, $SD = 1.16$ and $M = 2.24$, $SD = 1.30$ for groups A-NT and A-N, respectively).

Scientific and Educational Significance

The findings provide important support for a dual-processing theory of multimedia learning, which predicts that students learn better with redundant rather than with non-redundant verbal explanations. When words are presented as speech and text either by themselves, or accompanied by simultaneous sounds or sequential pictures, students are able to increase their effective working memory capacity by processing the verbal message in both modalities. More cognitive resources are available for making connections between corresponding words and pictures or sounds therefore increasing the chances for meaningful learning. However, if pictures are presented simultaneously with spoken and written messages--such as in the case of the studies conducted by Kalyuga et al. (1998, 1999), the visual working memory becomes overloaded. In this case, fewer cognitive resources are available for making connections between corresponding verbal and non-verbal representations, thus decreasing the chances for meaningful learning. In sum, the apparent discrepancy found in past literature is resolved by applying the cognitive theory of multimedia learning.

On the practical side, the present study contributes to the growing research base on multimedia design. Are two modalities of verbal information better than one? We believe that the answer to this question is relative. According to our cognitive theory of multimedia learning, verbal redundancy is not always effective or ineffective. When a multimedia explanation is presented using simultaneous visual information and when the material is presented at a rapid pace without opportunity for learner control of the presentation, removing the redundant on-screen text provides the best learning conditions by preventing students' visual working memory from becoming overloaded (Moreno & Mayer, 1999a; 1999b). However, presenting words in spoken and printed form might be useful in other learning situations, such as when students need to remember and understand what is being presented in the course of a verbal presentation or lecture. In this case, presenting summary slides or writing the key ideas of the lecture on a board is more likely to promote students' learning.

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