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Revising the Redundancy Principle in Multimedia Learning

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College students viewed a short multimedia PowerPoint presentation consisting of 16 narrated slides explaining lightning formation (Experiment 1) or 8 narrated slides explaining how a car's braking system works (Experiment 2). Each slide appeared for approximately 8–10 s and contained a diagram along with 1–2 sentences of narration spoken in a female voice. For some students (the redundant group), each slide also contained 2–3 printed words that were identical to the words in the narration, conveyed the main event described in the narration, and were placed next to the corresponding portion of the diagram. For other students (the nonredundant group), no on-screen text was presented. Results showed that the group whose presentation included short redundant phrases within the diagram outperformed the nonredundant group on a subsequent test of retention (d = 0.47 and 0.70, respectively) but not on transfer. Results are explained by R. E. Mayer's (2001, 2005a) cognitive theory of multimedia learning, in which the redundant text served to guide the learner's attention without priming extraneous processing.

Keywords: educational technology, multimedia learning, redundancy effect, PowerPoint presentation

Suppose you want to explain how lightning storms develop or how a car's braking system works to students who lack relevant prior knowledge, so you design a concise, narrated animation using the following research-based principles of effective instructional design (Fletcher & Tobias, 2005; Mayer, 2001, 2005b, 2005c, 2005d):

1. The *multimedia principle*—you use both words (as spoken text) and pictures (as animation or a series of still frames).

2. The *coherence principle*—you minimize any extraneous words or pictures.

3. The *modality principle*—you present the words as narration rather than as on-screen text.

4. The *temporal contiguity principle*—you present the narration at the same time the corresponding event is depicted in the graphics.

On subsequent retention tests (e.g., in which you ask the learner to write an explanation) or transfer tests (e.g., in which you ask the learner to write why the system might not work or how to improve it), learners perform better than if the principles were not implemented (e.g., no pictures were presented, extraneous words were included in the narration, or the narration was presented before or after the graphics).

What can you do to improve upon such seemingly effective lessons? You might be tempted to incorporate on-screen text, in which a caption appears at the bottom of the screen that contains the same words that are being spoken in the narration. As soon as the narrator begins a sentence, it appears on the bottom of the screen, and it stays on the screen until the narrator finishes the sentence.

Does adding redundant on-screen text help students learn? Previous research has shown students learn better from multimedia lessons containing graphics and narration than from graphics, narration, and redundant on-screen text (Kalyuga, Chandler, & Sweller, 1999, 2000, 2004; Leahy, Chandler, & Sweller, 2003; Mayer, Heiser, & Lonn, 2001; Moreno & Mayer, 2002a, 2002b; Mousavi, Low, & Sweller, 1995). This finding is known as the *redundancy effect* (Mayer, 2001, 2005c). For example, in a study by Moreno and Mayer (2002b), participants viewed an animation about lightning formation. The first condition had narration accompany the animation, whereas a second condition received redundant on-screen text in addition to the animation and narration. The group that received the redundant on-screen text performed worse on subsequent retention and transfer questions than did the group that received animation and narration; thus, a redundancy effect was found.

In most of the studies investigating the redundancy effect, including the one just discussed, the narration and the on-screen text were identical (Mayer, 2005c; Sweller, 1999, 2005), thus violating the coherence principle which, as mentioned above, states that unnecessary words or graphics should be eliminated (Mayer, 2001, 2005c). In addition, in many of the studies, including the one just discussed, the text was presented at the bottom of the screen, thus violating the *spatial contiguity principle*, which states that corresponding words and pictures in a multimedia presentation should be presented near each other on the screen (Ayres & Sweller, 2005; Mayer, 2001, 2005c).

Why does redundancy hinder learning? According to the cognitive theory of multimedia learning (Mayer, 2001, 2005a) shown in Figure 1, meaningful learning occurs when learners are able to pay attention to relevant portions of the words and graphics as they are registered in sensory memory (i.e., indicated by the "selecting words" and "selecting images" arrows), mentally organize them into coherent cognitive structures in working memory (i.e., indi-

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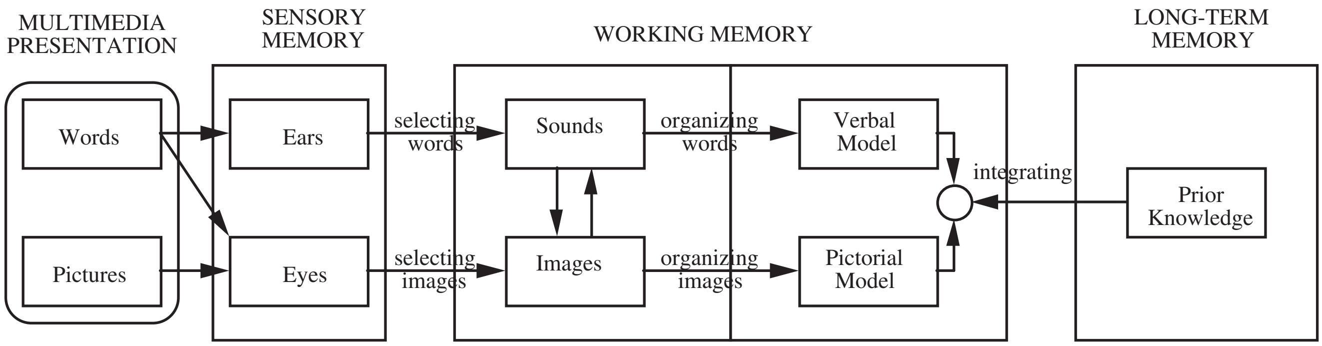

Figure 1. Cognitive theory of multimedia learning.

cated by the "organizing words" and "organizing images" arrows), and connect the verbal and pictorial representations with each other and with relevant knowledge retrieved from long-term memory (i.e., indicated by the "integrating" arrows). Although the integrating arrows are shown in working memory, the model assumes that the newly constructed knowledge is stored in long-term memory (using a process that can be called *encoding*).

Overall, the instructional message should be designed to reduce extraneous processing (i.e., processing that does not contribute to learning, such as visual scanning between the printed captions and the graphics), manage essential processing (i.e., processing aimed at selecting the relevant words and images so they can be represented in working memory), and foster generative processing (i.e., deeper processing in which the learner organizes and integrates the material). Adding redundant on-screen text detracts from the learning processes highlighted in Figure 1 because it creates extraneous processing—such as inducing the learner to visually scan between the caption at the bottom of the screen and the graphic and to try to mentally reconcile the incoming spoken and verbal stream. If the learner has to waste limited cognitive capacity on extraneous processing, the learner will be less able to engage in the cognitive processing needed for learning—essential and generative processing.

In spite of these empirical and theoretical setbacks for adding redundant on-screen text, in the current study we sought to determine whether there are conditions under which redundant on-screen text can foster rather than hinder learning. Consider a multimedia presentation on lightning formation consisting of 16 PowerPoint slides, each accompanied by approximately 10 s of narration, such as exemplified in the left panel of Figure 2 (i.e., the nonredundant presentation). To help learners direct their auditory attention to the key event being described in the narration, we can print a two- or three-word description of the event on the screen (using words from the narration). To help learners direct their visual attention to the key portion of the diagram, we can place the words next to the event they describe in the diagram. The right panel of Figure 2 exemplifies how we implemented the redundant words in the diagram (i.e., the redundant presentation). The goal of this manipulation is to facilitate the first step in the cognitive theory of multimedia learning—*selecting relevant words and images* (Mayer, 2001, 2005a). Success in selecting relevant words and images is most important for subsequent tests of retention of the presented material. Thus, based on the cognitive theory of multimedia learning, we predicted that the redundant group would outperform the nonredundant group on a retention test.

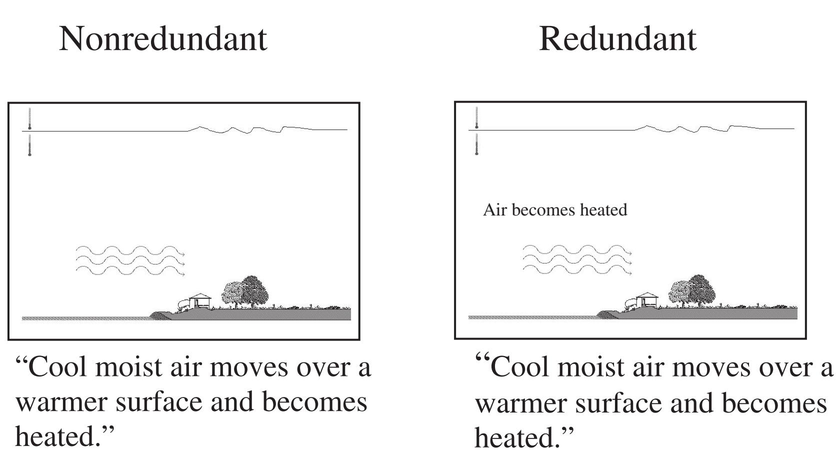

Figure 2. Example slide from the nonredundant (left panel) and redundant (right panel) versions of the lightning lesson.

This implementation of redundancy as short, on-screen labels avoids two major problems with previously studied redundancy presentations in which the entire text of the narration is printed at the bottom of the screen. First, by using only two or three keywords, the learner does not have to engage in reading the entire sentence; second, by placing the words next to the corresponding elements in the diagram, the learner does not need to scan from the bottom of the screen to various points in the diagram. Thus, we have attempted to create redundancy in a way that minimizes extraneous cognitive processing (namely, not requiring the learner to read an entire sentence or visually scan the diagram) while facilitating essential cognitive processing (namely, guiding the learner's selection of relevant words and images). Based on this interpretation of the cognitive theory of multimedia learning, we predict that adding on-screen labels to narrated graphics will result in improved performance on tests of retention (which are intended to be sensitive to instruction that guides the learner's attention) and will not hinder performance on tests of transfer (which are intended to measure deeper processing during learning). It is possible that the treatment could improve performance on transfer by freeing up cognitive capacity to engage in deeper processing, although the main manipulation in this study is intended to pinpoint the most important words in the narration.

Experiment 1 (Lightning)

The purpose of Experiment 1 was to determine the cognitive consequences of adding short, redundant on-screen text to a multimedia lesson.

Participants and Design

Ninety undergraduates from the University of California, Santa Barbara, psychology student subject pool participated in this study for course credit. The mean age was 18.29 years ($SD = .75$), and there were 58 women and 32 men. Forty-five participants served in the nonredundant group, and 45 participants served in the redundant group.

Method

Materials and apparatus. The paper-based materials consisted of a participant questionnaire, a retention test question, and four transfer test questions, each typed on an 8.5- × 11-in. sheet of paper. The participant questionnaire solicited information concerning the participant's age, sex, and prior knowledge. The retention test question was "Please write down an explanation of how lightning works." The retention test was intended to measure the student's memory for the presented material—corresponding to remembering factual and conceptual knowledge in Bloom's taxonomy (Anderson et al., 2001). The transfer test questions were as follows: (a) "What could you do to decrease the intensity of lightning?" (b) "Suppose you see clouds in the sky but no lightning. Why not?" (c) "What does air temperature have to do with lightning?" and (d) "What causes lightning?" The transfer test was intended to measure the student's understanding of the presented material—corresponding to understanding and applying conceptual knowledge in Bloom's taxonomy (Anderson et al., 2001).

The computer-based materials consisted of nonredundant and redundant versions of a PowerPoint lesson on lightning formation. The presentation included diagrams and simultaneous narration shown via PowerPoint and consisted of 16 individual slides, lasting approximately 2.5 min. The slides advanced automatically after the narration was complete, averaging approximately 9.5 s per slide. The slides for the redundant group included two or three action-oriented keywords from the narration and were presented within the diagram next to the elements they described. The words expressed the main action depicted in the slide. For example, for the slide containing the narration, "Cool moist air moves over a warmer surface and becomes heated," the keywords "air becomes heated" were printed in the diagram next to the heated air mass. The slides for the nonredundant group contained no printed words. Examples of redundant and nonredundant slides are shown in Figure 2.

The apparatus consisted of five Macintosh iBook computers with Panasonic headphones. A stopwatch was used to time the retention and transfer tests.

Procedure. Students were tested in groups of 1 to 5 per session, with each student seated in an individual cubicle containing a Macintosh iBook computer with Panasonic headphones. Students were told they would view a lesson on lightning formation and then they would answer some questions based on the material. Each student completed the participant questionnaire, then watched a short PowerPoint presentation about lightning formation on the computer, and finally answered a series of timed, open-ended questions about the material consisting of one retention question and four transfer questions. Half of the participants were randomly assigned to the nonredundant group (which received graphics and narration), and half were randomly assigned to the redundant group (which received graphics, narration, and on-screen text). Following the presentation, all students wrote their answers for the retention test question (with a 5-min time limit) and each of the transfer test questions (with a 3-min time limit per question). Upon completion of the tests, students were thanked and debriefed. The materials and procedure were adapted from previous research using a narrated animation on lightning formation (Mayer et al., 2001; Moreno & Mayer, 2002b).

Results and Discussion

The dependent variables were the scores on the retention and transfer tests; the independent variable was whether or not the presentation included redundant text. In order to score the retention test, we broke the lightning script into 16 idea units, each expressing a main event such as "cool air moves over warmer surface and becomes heated." Each student's retention test was scored by assigning 1 point for each idea unit that the student wrote down, regardless of wording or spelling (out of a total possible of 16 points), such as "cold air gets hotter." For the transfer tests, a list of acceptable answers was created for each question. For example, for the question about decreasing the intensity of lightning, correct answers included removing positive ions from the ground and placing positive ions near the cloud. One point was awarded for each correct answer, and the points for each question were added up to compute the total transfer score (out of a total possible of 12 points), which was used in the analyses.

Table 1 presents the means and standard deviations of the two groups on the retention and transfer tests. Independent samples *t* tests revealed that the redundant group ($M = 8.02$, $SD = 2.83$) scored significantly better than the nonredundant group ($M = 6.69$, $SD = 2.87$) on the retention test, $t(88) = 2.22$, $p < .05$, $d = 0.47$, whereas the redundant group ($M = 3.60$, $SD = 2.00$) and the nonredundant group ($M = 3.67$, $SD = 2.04$) did not differ significantly on the transfer test, $t(88) = 0.16$, $p = .88$, $d = 0.04$.

Results can be explained in terms of Mayer's (2001, 2005a) cognitive theory of multimedia learning. Essential processing was fostered by the redundant treatment because the on-screen text helped guide the learners' attention to the relevant words—which was reflected in retention test performance. However, the redundant on-screen text was not intended to encourage generative processing (i.e., deeper cognitive processing), such as organizing the material into a coherent representation and integrating it with existing knowledge—which would be reflected in transfer test performance. Extraneous processing was kept low in the redundant condition by minimizing the amount of on-screen text (rather than reproducing all of the text) and placing it next to the corresponding portion of the diagram (rather than at the bottom).

Experiment 2 (Brakes)

The purpose of Experiment 2 was to determine whether the pattern of results obtained in Experiment 1 could be replicated with different instructional materials.

Participants and Design

Sixty-two undergraduate students from the University of California, Santa Barbara, psychology student subject pool participated in this study for course credit. The mean age of participants was 18.6 years ($SD = 1.2$), and there were 27 women and 35 men. Thirty-one participants served in the nonredundant group, and 31 participants served in the redundant group.

Method

Materials and apparatus. The paper-based materials consisted of a participant questionnaire, a retention test question, and five transfer test questions, each typed on an 8.5- × 11-in. sheet of paper. The participant questionnaire solicited information concerning the participant's age, sex, and prior knowledge. The retention test question was "Please write down an explanation for how a car's braking system works." The transfer test questions were as follows: (a) "Why do brakes get hot?" (b) "What could be done to make brakes more reliable, that is, to make sure they do not fail?" (c) "What could be done to make brakes more effective, that is, to reduce the distance needed to bring the car to a stop?" (d) "Suppose you press on the brake pedal in your car but the brakes don't work. What could have gone wrong?" and (e) "What happens when you pump the brakes (i.e., press the pedal and release the pedal repeatedly and rapidly)?"

The computer-based materials consisted of nonredundant and redundant versions of a PowerPoint lesson on how a car's braking system works. The presentation included diagrams and simultaneous narration shown via PowerPoint and consisted of eight individual slides, lasting approximately 80 s. The slides advanced automatically after the narration was complete, averaging approximately 10 s per slide. The slides for the redundant group included two or three action-oriented keywords from the narration and were presented within the diagram next to the elements they described. The words expressed the main action in the slide. For example, for the slide containing the narration, "a piston moves forward inside the master cylinder," the keywords "piston moves forward" were printed in the diagram next to the piston in the master cylinder. The slides for the nonredundant group contained no printed words. An example of a redundant slide is presented in Figure 3.

The apparatus consisted of five Macintosh iBook computers with Panasonic headphones. A stopwatch was used to time the retention and transfer tests.

Procedure. Students were tested in groups of 1 to 5 per session, with each student seated in an individual cubicle containing a Macintosh iBook computer with Panasonic headphones. Students were told they would view a lesson on how car brakes work, and then would answer some questions based on the material in the lesson. Each student completed the participant questionnaire, then watched a short PowerPoint presentation about car brakes on the computer, and finally answered a series of timed, open-ended questions about the material consisting of one retention question and five transfer questions. Half of the participants were randomly assigned to the nonredundant group (which received graphics and narration), and half were randomly assigned to the redundant group (which received graphics, narration, and on-screen text). Following the presentation, all students wrote their answers for the retention test question (with a 4-min time limit) and each of the transfer test questions (with a 2.5-min time limit per question). Upon completion of the tests, students were thanked and debriefed. The materials and procedure were adapted from previous research using a narrated animation on how brakes work (Mayer & Anderson, 1991; Mayer & Moreno, 1998).

Results and Discussion

The dependent variables were the scores on the retention and transfer tests; the independent variable was whether or not the presentation included redundant text. The retention tests were scored by breaking the lesson into eight idea units, each conveying one action, such as "the piston moves forward in the master cylinder." Students received 1 point for each idea unit they wrote down on their retention test (out of a total possible of 8 points), regardless of spelling or wording. For the transfer tests, we developed a list of acceptable answers for each question. For example, for the question about what could be wrong, possible answers

Table 1
Mean Retention and Transfer Scores for Two Groups—Experiment 1 (Lightning Lesson)

Score type and group	*M*	*SD*	*p*	*d*
Retention				
Nonredundant	6.7	2.9	.03	0.47
Redundant	8.0	2.8		
Transfer				
Nonredundant	3.6	2.0	.88	0.04
Redundant	3.7	2.0		

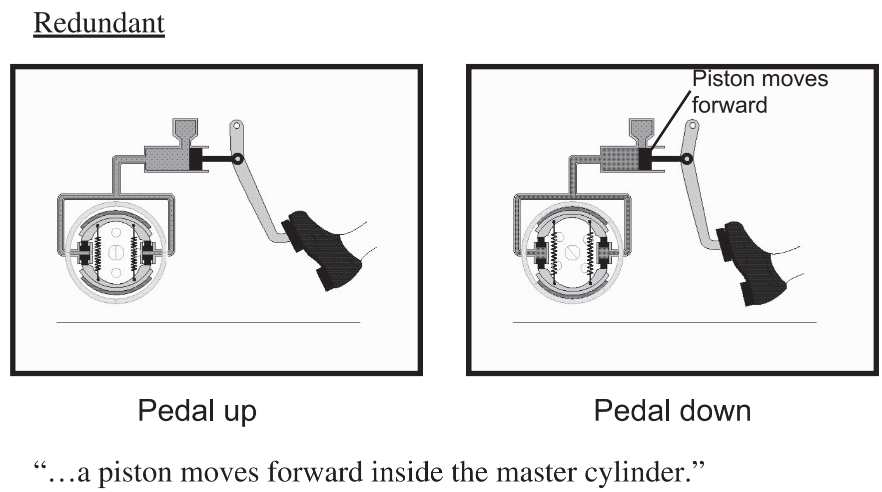

Figure 3. Slide from the redundant version of the brake lesson; the nonredundant version did not contain the on-screen text.

included that the piston was stuck or there was a leak in the brake tube. One point was awarded for each correct answer, and the points for each question were added up to compute the total transfer score (out of 14 possible points), which was used in the analyses.

Table 2 summarizes the means and standard deviations for the two groups on the retention and transfer tests. Independent samples t tests revealed that the redundant group (M = 5.13, SD = 1.98) scored significantly better than the nonredundant group (M = 3.61, SD = 2.35) on the retention test, $t(60) = 2.75$, $p = .008$, $d = 0.70$, whereas the redundant group (M = 3.90, SD = 1.76) and the nonredundant group (M = 4.16, SD = 2.16) did not differ significantly on the transfer test, $t(60) = 0.52$, $p = .608$, $d = 0.15$.

The pattern of results in Experiment 2 replicates that in Experiment 1 and supports the theoretical explanation that short, redundant on-screen text can guide the learner's attention toward relevant words (i.e., essential processing) without increasing extraneous processing or fostering generative processing.

Conclusion

Main Empirical Findings

In two separate experiments, adding short, redundant text to narrated graphics resulted in improvements on retention of the verbal material but not on transfer. The effect size—favoring the redundant group—was in the medium range, indicating that the redundancy effect was practically important as well as statistically significant.

Table 2
Mean Retention and Transfer Scores for Two Groups—Experiment 2 (Brakes Lesson)

Score type and group	*M*	*SD*	*p*	*d*
Retention				
Nonredundant	3.6	2.3	.008	0.70
Redundant	5.1	2.0		
Transfer				
Nonredundant	4.2	2.2	.61	0.15
Redundant	3.9	1.8		

Theoretical Implications

The pattern of results is consistent with the predictions of the cognitive theory of multimedia learning, in which short on-screen labels are intended to guide the cognitive process of selecting relevant words and images while not creating extraneous processing. In previous studies, adding redundant on-screen text to narrated graphics (i.e., complete reproductions of the narration as captions at the bottom of the screen) resulted in decreases in both retention and transfer test performance (Mayer, 2001, 2005c).

There were three main differences in the way redundancy was implemented in the present study in comparison with previous studies that yielded a redundancy effect. First, the on-screen text was short rather than long: Short text, consisting of two or three words, was intended to guide essential processing while not creating extraneous processing, whereas long on-screen text does not guide essential processing while creating the need for extraneous processing.

Second, the on-screen text was placed near rather than far from the corresponding portion of the graphic: Contiguous presentation of corresponding words and graphics is intended to minimize extraneous processing while guiding the learner's attention toward the relevant portion of the graphic, whereas separated presentation induces extraneous processing while not guiding the learner's attention. When sentences from the narration are printed in their entirety as text at the bottom of the screen, learners may engage in extraneous cognitive processing that results in poorer performance on subsequent tests (Mayer, 2001, 2005c). In contrast, when a few keywords are printed next to the corresponding portion of the diagram, learners may be better able to engage in essential cognitive processing (such as selecting relevant words and images) that results in improved performance on subsequent tests.

Table 3
When Redundancy Supports or Hinders Learning

Action	Condition
Redundancy supports learning	When it minimizes extraneous processing—by placing text near rather than far from corresponding graphics When it fosters essential processing—by highlighting key portions of the text rather than presenting all text (or when text is complex)
Redundancy hinders learning	When it creates extraneous processing—by placing text far from rather than near corresponding graphics When it detracts from essential processing—by highlighting the entire text rather than highlighting key portions of the text

Third, the present study presented graphics as a series of static illustrations rather than as an animation as in previous experiments. The motion in an animation may help direct the learner's attention to the relevant portion of the graphic, but there are no motion cues in a static illustration. Therefore, redundant on-screen phrases may be particularly helpful for directing the learner's attention with static illustrations.

Practical Implications

Concerning educational implications, this study helps to establish some boundary conditions for determining when redundancy can be helpful or harmful in multimedia learning. The most straightforward contribution of this work is to add an important caveat to the redundancy principle "People learn more deeply from graphics and narration than from graphics, narration, and on-screen text" (Mayer, 2005c, p. 193).[1] In revising this statement of the redundancy principle, we can add the following limitation: "except when the on-screen text is short, highlights the key action described in the narration, and is placed next to the portion of the graphic that it describes." In short, this work pinpoints an important boundary condition for applying the redundancy principle—it applies most strongly when the on-screen text reproduces the complete narration and appears at the bottom of the screen, and it does not necessarily apply when the on-screen text consists of a few core words placed next to the relevant portion of the graphic. Table 3 summarizes the conditions under which redundancy can hinder or help learning. We also suspect that other boundary conditions include when the spoken text is complex, contains unfamiliar words, or is not in the learner's native language; when the pace of the presentation is slow or under the learner's control; or when no graphics are presented (Mayer, 2001, 2005c).

A broader contribution of this work is to highlight the admonition that design principles for multimedia messages, such as the 10 principles proposed by Mayer (2001, 2005b, 2005c, 2000d), are not rigid laws that must be followed in all circumstances. Rather, decisions about appropriate instructional design should be based on an understanding of how people learn from words and pictures, such as the cognitive theory of multimedia learning (Mayer, 2001, 2005a) or cognitive load theory (Sweller, 1999, 2005). Thus, the challenge for instructional designers is to apply design principles in ways that reduce extraneous processing (such as scanning between captions and the graphic), manage intrinsic processing (such as attending to relevant portions of the narration and graphic), and foster generative processing (such as mentally organizing and integrating the material). The revision to the redundancy principle is necessary because the use of short labels helps manage essential processing (by guiding the learner's attention to the keywords in the narration and the key action in the graphic) while not adding to extraneous processing (by presenting only a few words and placing them next to the portion of graphic they describe). In summary, rather than blindly following design rules, instructional designers should always consider how applying a rule will affect the learner's cognitive processing during learning, particularly the degree to which applying the principle is likely to lead to reducing extraneous processing, managing intrinsic processing, and fostering generative processing.

Limitations and Future Directions

These studies were conducted as short laboratory experiments, but future work is needed to determine whether the findings generalize to more realistic educational settings. Future work also is needed to determine whether the results would be obtained if the words in the narration were presented as on-screen captions rather than narration. Finally, although there were no differences between the groups on the transfer test, it is possible that more sensitive measures might be able to detect a difference in future work. However, the transfer scores were not near either ceiling or floor, and the same transfer test has yielded significant differences between treatment groups in other experiments (Mayer, 2001).

[1] Sweller (1999, 2005) uses a broader definition of the redundancy principle in which learning is hindered when "the same material is presented in multiple forms" (Sweller, 2005, p. 159). This definition includes our definition of redundancy but also includes additional situations that we did not investigate.

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