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When Learning Is Just a Click Away: Does Simple User Interaction Foster Deeper Understanding of Multimedia Messages?

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In 2 experiments, students received 2 presentations of a narrated animation that explained how lightning forms followed by retention and transfer tests. In Experiment 1, learners who were allowed to exercise control over the pace of the narrated animation before a second presentation of the same material at normal speed (part–whole presentation) performed better on transfer but not retention tests compared with learners who received the same 2 presentations in the reverse order (whole–part presentation). In Experiment 2, learners who were allowed to exercise control over the pace of the narrated animation across 2 presentations (part–part presentation) performed better on transfer but not retention tests compared with learners who received the same 2 presentations at normal speed without any learner control (whole–whole presentation). These results are consistent with cognitive load theory and a 2-stage theory of mental model construction.

The goal of the research discussed in this article was to determine the possible benefits of incorporating a modest amount of computer–user interactivity (which we call *simple user interaction*) within a multimedia explanation. However, to address this issue clearly it is necessary to define the terms *multimedia explanation, simple user interaction,* and *cognitive consequence of simple user interaction.*

Definitions

What Is a Multimedia Explanation?

A *multimedia explanation* consists of words (e.g., narration) and pictures (e.g., animation) that provide a cause-and-effect account of how some system works (e.g., the formation of lightning). A cause-and-effect system exists when there is a series of interacting parts such that a change in state in one part causes a change in state in another part and so on (e.g., when cool air is heated it rises) and in which the changes are based on principles rather than arbitrary links (e.g., heated air rises because it is less dense than the surrounding air). For example, Figure 1 shows selected frames from a narrated animation on lightning formation in which the animation depicts the steps in the formation of lightning and the narration describes those steps. Previous research has demonstrated that this type of narrated animation is highly effective in promoting understanding in learners, as indicated by high levels of performance on tests of problem-solving transfer (Kalyuga, Chandler, & Sweller, 1999, 2000; Mayer, 1997, 1999, 2001; Mayer & Moreno, 1998; Moreno & Mayer, 1999).

What Is Simple User Interaction in a Multimedia Explanation?

Simple user interaction in a multimedia explanation refers to user control over the words and pictures that are presented in the multimedia explanation. For example, the 16 frames in Figure 1 represent 16 segments in the lightning presentation. In an interactive version of the multimedia explanation, a button labeled "Click here to continue" appears in the lower right corner of the screen at the end of each segment. When the user clicks on the button, the computer presents the next segment then waits for the next click. In this way, the user can control one modest yet critical aspect of the multimedia explanation—namely, the pace of the presentation. Conventional computer-based animation tends to present information in a continuous manner such that the entire system is displayed without any breaks. Although some computer-based animations have "repeat" options that allow the animation to be replayed in its entirety, they rarely provide simple interactivity that allows the learner control of the flow of the presentation. Furthermore, if a control mechanism is available, it usually is operational only after the presentation has been demonstrated at normal speed.

What Is Cognitive Consequence of Simple User Interaction in a Multimedia Explanation?

Simple user interaction may affect both cognitive processing during learning and the cognitive outcome of learning. As for cognitive processing during learning, we propose that simple user interaction has two important effects on the learning process: It (a) reduces the learner's cognitive load on working memory, (b) thereby enabling the learner to progressively build a coherent

Roxana Moreno created the original multimedia programs on lightning formation. Chad Vachar modified the programs to enable computer–user interactivity. Sarah Mayer assisted in data collection, scoring, and analysis.

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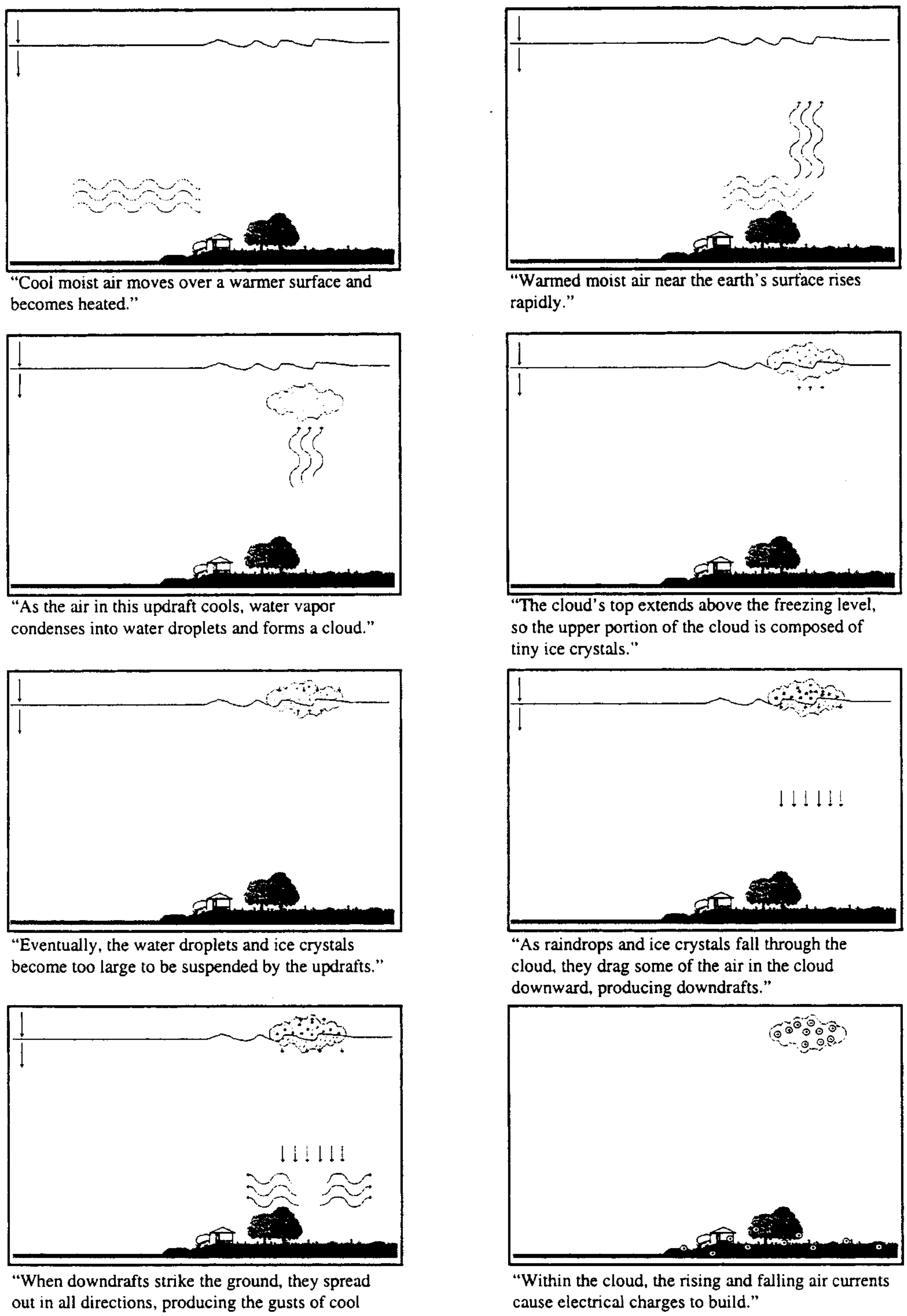
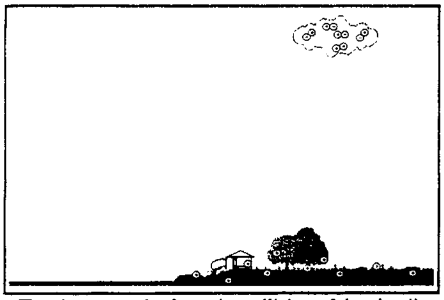


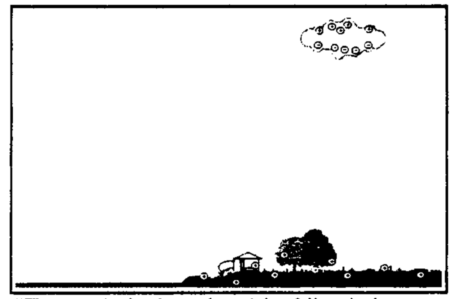
Figure 1. Selected frames and corresponding narration for multimedia explanation on lightning formation. *(Figure continues)*

mental model.[1] First, consider the role of cognitive load. When the lightning explanation is presented in the conventional manner (i.e., all at once with no opportunities for breaks; whole presentation), the flow of words and pictures into working memory may become overwhelming. Assuming that processing capacity is limited, learners must devote so much processing capacity simply to receiving the incoming words and pictures that they have no capacity

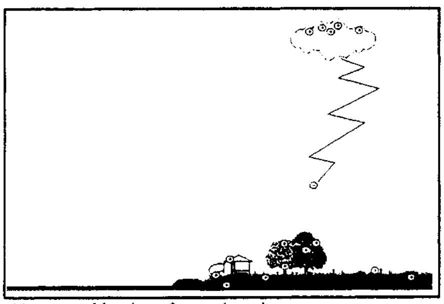
[1] We consider a mental model to be a particular type of schema.



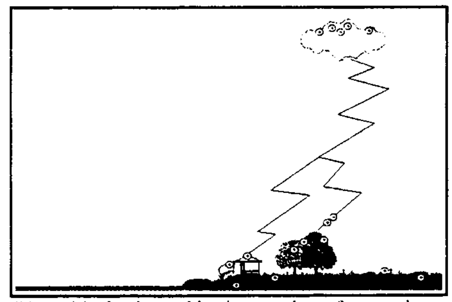
"The charge results from the collision of the cloud's rising water droplets against heavier, falling pieces of ice."



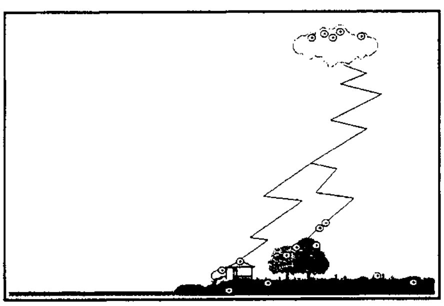
"The negatively charged particles fall to the bottom of the cloud, and most of the positively charged particles rise to the top."



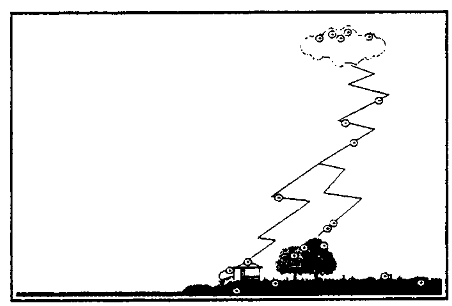
"A stepped leader of negative charges moves downward in a series of steps. It nears the ground."



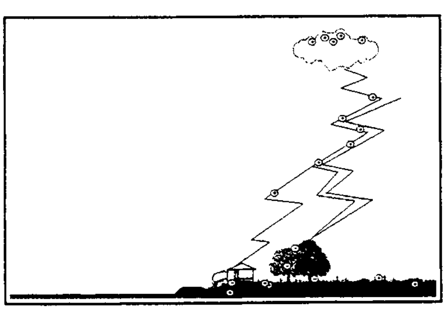
"A positively charged leader travels up from such objects as trees and buildings."



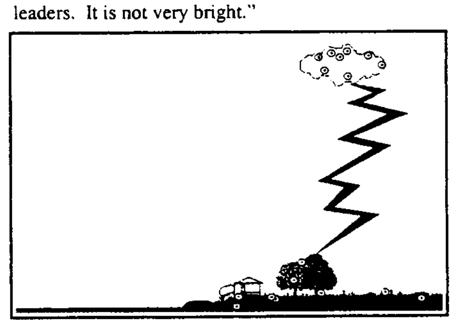
"The two leaders generally meet about 165-feet above the ground."



"Negatively charged particles then rush from the cloud to the ground along the path created by the leaders. It is not very bright."



"As the leader stroke nears the ground, it induces an opposite charge, so positively charged particles from the ground rush upward along the same path."



"This upward motion of the current is the return stroke. It produces the bright light that people notice as a flash of lightning."

Figure 1 (*continued*).

left to mentally organize the incoming material or mentally integrate it with other knowledge. Previous multimedia research has shown that when many learning elements need to be processed and related simultaneously, as is the case with narrated animations of cause-and-effect systems, cognitive load becomes high and understanding of complex concepts can be hindered (Chandler & Sweller, 1991, 1996; Sweller & Chandler, 1994; Tindall-Ford, Chandler, & Sweller, 1997). Thus, although learners may perform satisfactorily on retention tests, deep understanding (as measured by transfer test performance) may be hindered by whole presentation methods. In contrast, when the lightning explanation is presented part by part under learner control (i.e., part presentation), the learner can strive to fully understand one segment before moving on to the next, thereby reducing the chance of cognitive overload. For example, in each segment, learners receive 10 s of animation and a sentence of narration. They can devote their full capacity to processing this amount of material. Thus, learners may have more opportunity to process and connect related information under a part presentation than under an equivalent whole presentation.

Second, in progressive model building, learners first build component models and then integrate them into a causal model. A component model is a representation of how one of the parts of the system works (i.e., the state change that takes place within that part). For example, the first segment in the lightning explanation describes in words how cool moist air moves over a warmer surface and becomes heated and shows in pictures how blue arrows move from left to right and turn red. Thus, the relevant component model focuses on changes in the location and temperature of an air mass: Air moves from a cool place to a warm place and changes from cool to warm. By allowing learners to focus on one segment at a time, part presentation is designed to help learners build component models.

A causal model is a cause-and-effect chain in which a state change in one component in the system causes another state change and so on. For example, the entire lightning explanation consists of a chain of events that are causally related such as air rising because it was heated. Assimilating this complex information with a high degree of connectedness between learning elements (e.g., warm surface, cool air, warm air, cloud, negatively charged particles, etc.) may impose a high cognitive load during learning from the whole presentation of the narrated animation. This load would be reduced if learners had previous experience with the component models, as would be expected if they had previously received the part presentation.

Regarding cognitive outcomes, simple user interaction may lead to deeper understanding of scientific systems, which is manifested in meaningful learning outcomes. In this study, we sought to measure meaningful understanding by giving learners a transfer test in which they were required to use the presented information in new ways that went beyond what was presented. For example, we asked learners to troubleshoot the lightning-formation system by writing an answer to the following question: "Suppose you see clouds in the sky but no lightning. Why not?" We also asked learners to redesign the lightning-formation system to meet a new functional requirement: "What could you do to reduce the intensity of a lightning storm?" Finally, we asked learners to abstract the underlying principles of lightning formation: "What does air temperature have to do with lightning?" or "What causes lightning?" We tallied the number of acceptable answers given across these transfer questions and used this as a gross measure of each learner's understanding of the material. If simple user interaction leads to deeper learning outcomes, then transfer test performance should reflect these deeper learning outcomes.

Predictions

Whole–Part Versus Part–Whole Presentation

By combining our assumptions of cognitive load and progressive model building, we were able to make predictions regarding various multimedia design options. For example, conventional practice is to present the entire sequence (i.e., continuous narrated animation with no learner control) followed by each segment separately (i.e., segment-by-segment presentation with learner control; whole–part [WP] presentation). The rationale for this is that seeing the entire presentation allows the learner to build a context that is then elaborated on in the second presentation, during which the learner can focus on each part of the system. When the material is presented in segments (i.e., segment-by-segment presentation under learner control) and then the whole presentation is shown (part–whole [PW] presentation), the learner is less able to build a unified context during the first presentation. According to this whole-first hypothesis, learners should learn more deeply from a WP presentation than from a PW presentation.

In contrast, the parts-first hypothesis is based on cognitive load theory (see Sweller, 1999, for a review). The parts-first hypothesis asserts that learners are more likely to experience cognitive overload when the whole presentation is given first and it therefore cannot serve as an effective context for organizing the subsequent parts presentation. Instead, when the parts presentation comes first, learners can build separate component models for each of the key parts of the system (e.g., changes in air mass, changes in electrical charge, etc.). These component models then serve as chunks that can be more easily organized into a mental model when the whole presentation is given. According to this hypothesis, learners should learn more deeply from a PW presentation rather than a WP presentation. In Experiment 1 we compared the retention and transfer performance of learners who received WP and PW presentations.

Whole–Whole Versus Part–Part Presentation

In a whole–whole (WW) presentation, learners receive the entire multimedia explanation and then receive it again. This is a conventional way of providing two presentations of a multimedia explanation. The whole-first hypothesis predicts better retention and transfer from a WW presentation than from a PP presentation. In contrast, in a part–part (PP) presentation, learners receive the parts presentation and then receive it again. It should be noted that this is an unconventional method for presenting narrated animations. According to the parts-first hypothesis, learners can build component models during the first portion of a PP presentation and then click quickly through the second portion, effectively turning it into a whole presentation if they wish. Even if they have only partially understood the workings of the components in the lightning system, for example, they still are able to control the flow of presentation in the second viewing. However, they will have more difficulty building component models during the first portion of a WW presentation and thus will be less likely to have a context available for building a causal model during the second presentation. According to the parts-first hypothesis, which is based on cognitive load theory, learners should learn more deeply from a PP presentation than from a WW presentation. In Experiment 2 we compared the retention and transfer performance of learners who received PP and WW presentations.

Previous research on learner control of the pacing of computer-based instruction has yielded disappointing and inconsistent results (Dillon & Gabbard, 1998; Niemiec, Sikorski, & Walberg, 1996; Williams, 1996). According to Reeves (1993), a major theoretical problem with this body of research is "the lack of theoretical foundations undergirding the experiments" (Williams, 1996, p. 963). Lepper (1985) reported that a major methodological problem with this body of research is that students in learner-controlled conditions select less material and thereby receive "an incomplete lesson compared with their program-controlled counterparts" (Williams, 1996, p. 963). We overcame this theoretical problem by basing our manipulations and predictions on a cognitive theory of multimedia learning and addressed this methodological problem by ensuring that all students received identical material.

Experiments 1 and 2

In Experiment 1, learners received two exposures to a 140-s multimedia explanation of lightning formation—a whole presentation in which the entire program was presented as a complete and continuous unit and a part presentation in which the learner clicked a button to view each of 16 successive segments. Some learners (PW group) received the parts presentation followed by the whole presentation, whereas the other learners (WP group) received the whole presentation followed by the parts presentation.

The WP approach is the conventional method of presenting a complex sequence: The learner sees the whole sequence first in order to build a coherent context and then sees each part separately to reinforce parts of the context. The WP approach has been considered to be an effective means of demonstrating psychomotor skills (see Kroehnert, 1995) and therefore has been adopted by many computer-based instructional developers in presenting animations. It is important to note that although this method of presentation traditionally has been favored by instructors, there is no convincing evidence in support of its effectiveness.

According to cognitive load theory, presenting the whole sequence first is likely to overload the cognitive system, making it difficult for the learner to derive a useful context from the presentation. The subsequent presentation of parts is not useful because the learner lacks a coherent context to connect it to. In contrast, the PW approach is preferred. Presenting the parts first allows the learner to build component models so that when the whole sequence is presented as a continuous unit the learner can connect it to this foundation and more easily form a causal model. Thus, according to cognitive load theory, the PW group should outperform the WP group on understanding the process of lightning formation, even though both groups receive identical information.

In Experiment 2, learners received two exposures to a 140-s multimedia explanation of lightning formation—two whole presentations in which the entire program was presented as a unit (WW group) or two part presentations in which the learner clicked a button to view each of 16 successive segments (PP group). According to the conventional approach to multimedia instruction, it may be better to show the entire sequence (as in the WW group) so as not to disrupt the flow of information to the learner. According to cognitive load theory, however, learners have a better chance of building a coherent mental model when working memory is not overloaded, so the PP group should perform best.

Method

Participants and design. The participants in Experiments 1 and 2 were 59 college students from the Psychology Subject Pool at the University of California, Santa Barbara. All participants lacked high familiarity with meteorology, as indicated by a score of 6 or less on a 12-item meteorology experience survey. In Experiment 1, 15 students served in the PW group and 15 served in the WP group. The mean age was 18.5 years for the PW group and 19.0 years for the WP group, $t(28) = -1.451$, $p = ns$. Mean combined Scholastic Aptitude Test (SAT) scores were 1201 for the PW group and 1226 for the WP group, $t(21) = -0.476$, $p = ns$. Mean score on the 12-item meteorology experience survey was 3.2 for the PW group and 2.7 for the WP group, $t(28) = 0.854$, $p = ns$. Mean proportion of women was .67 for both the WP and PW groups.

In Experiment 2, 15 students served in the PP group and 14 served in the WW group. Mean age was 18.9 years for the PP group and 18.7 years for the WP group, $t(27) = 0.656$, $p = ns$. Mean combined SAT scores were 1093 for the PP group and 1185 for the WW group, $t(20) = -1.838$, $p = .08$. Mean score on the 12-item meteorology experience survey was 2.5 for both the PP and WW groups, $t(27) = 0.066$, $p = ns$. Mean proportion of women was .87 for the PP group and .93 for the WW group, yielding a nonsignificant difference ($\alpha = .05$) based on a Fisher's exact test.

Materials and apparatus. The paper-based materials consisted of a one-sheet participant questionnaire, a subjective cognitive load rating sheet for Part 1, a subjective cognitive load rating sheet for Part 2, a one-sheet retention test, and a four-sheet transfer test.[2] Each sheet was 8.5 × 11 in. with print only on one side. The participant questionnaire asked participants to indicate their age, gender, SAT scores, and level of meteorological experience. Meteorological experience was assessed by a 5-item self-rating and a 7-item checklist. The self-rating asked participants to "please put a check mark indicating your knowledge of meteorology (weather)" using a 5-point scale ranging from *very little* (1) to *very much* (5). The checklist contained the instruction to "Please place a check mark next to the items that apply to you" followed by a list of 7 items: "I regularly read the weather maps in the newspaper." "I can distinguish cumulus and nimbus clouds." "I know what a low pressure system is." "I can explain what makes the wind blow." "I know what this symbol means: [symbol for cold front]." "I know what this symbol means: [symbol for warm front]."

The cognitive load rating sheet for Part 1 contained the following question and instruction: "How difficult was it for you to learn about lightning from the presentation you just saw? Please place a check mark indicating your rating. ____ (1) very easy, ____ (2) somewhat easy, ____ (3) slightly easy, ____ (4) medium, ____ (5) slightly hard, ____ (6) somewhat hard, ____ (7) very hard." The rating sheet for Part 2 was identical except that the following was inserted at the end of the question: "(i.e., the presentation that came on after your last rating)." Subjective self-ratings were chosen to measure cognitive load because they are easy to implement, do not intrude on the main instructional task, and have been used successfully in previous research (Kalyuga et al., 1999, 2000, in press; Paas & Van Merrienboer, 1993, 1994).

The retention test consisted of the following instruction printed at the top of the page: "Please write down an explanation of how lightning works." The four sheets of the transfer test contained the following questions at the top of each sheet, respectively: "What could you do to decrease the intensity of lightning?" "Suppose you see clouds in the sky but no lightning. Why not?" "What does air temperature have to do with lightning?" and "What causes lightning?" The following instructions were printed in

[2] In addition, after all other tests, we administered an 8-item matching test. We did not use this test in our analysis, however, because it proved to be too easy for most participants.

all capital letters at the bottom of each sheet in both the retention and transfer tests: "PLEASE KEEP WORKING UNTIL YOU ARE TOLD TO STOP."

In Experiment 1, the computer-based materials consisted of two multimedia programs: the PW program and the WP program. The PW program consisted of a frame asking the learner to click the mouse to begin, the part presentation of how lightning works, a frame asking the learner to fill out a rating sheet placed next to the computer, a frame asking the learner to click the mouse to begin the next part of the presentation, the whole presentation of how lightning works, and a frame asking the learner to fill out a second rating sheet. The WP program was identical except the whole presentation came before the part presentation. The whole presentation consisted of a 140-s narrated animation describing the steps in lightning formation. Selected frames and the corresponding narration are shown in Figure 1. The part presentation was identical to the whole presentation except that it was broken into 16 segments, as represented by each of the 16 frames in Figure 1. At the end of each of the 16 segments, a button labeled "Click here to continue" appeared in the lower right corner of the screen. The next segment was presented as soon as the learner clicked on the button. Each segment presented approximately 10 s of animation and one sentence of narration. The part presentation was intended to give the learner control over the rate of presentation and thereby reduce cognitive load during learning. The programs were constructed using Director 6.0 for the Macintosh (Macromedia, 1997a) and Soundedit 16 for the Macintosh (Macromedia, 1997b).

The materials used in Experiment 2 were identical to those used in Experiment 1 except the two multimedia programs were PP (i.e., two part presentations) and WW (i.e., two whole presentations).

The apparatus consisted of four Macintosh G3 computer systems with 15-in. color monitors and Sony headphones.

Procedure. Participants were tested in groups of 1 to 4 per session, and each participant was randomly assigned to an instructional group. Each participant was seated in an individual cubicle facing a computer monitor connected to headphones and a mouse. First, the participants filled out the participant questionnaire at their own rates. Then, participants were given brief instructions in which they were told they would be learning about "how lightning storms develop" and that afterward they would be given some questions to answer. The experimenter told the participants to put on the headphones and click the mouse when they were ready to begin. The computer then presented the appropriate multimedia presentation (i.e., part or whole), followed by a frame asking the participant to complete the subjective cognitive load rating form. At this point, the experimenter distributed the first rating sheet, the participant completed it, and then the participant was told to click the mouse to proceed. The computer then presented the next multimedia presentation according to the participant's treatment condition (i.e., part or whole), followed by a frame asking the participant to complete another rating form. At this point, the experimenter distributed the second rating sheet, the participant completed it, and the participant was instructed to remove the headphones.

After a brief introduction, the experimenter passed out the retention test and asked the participants to "Please write down an explanation of how lightning works" and to "please keep working until I tell you stop." The retention test was collected after 6 min. Next, the experimenter distributed the first sheet of the transfer test and asked participants to "Please write your answer for this question and please keep working until I tell you to stop." After 2.5 min., the sheet was collected and each of the next test sheets was administered in the same way. After the last sheet, participants were debriefed and thanked for their participation.

Results and Discussion

Both groups in Experiment 1 were exposed to identical material—one whole and one part presentation of the multimedia explanation. Accordingly, we expected both groups to perform at equivalent levels in remembering the major idea units on the retention test. As shown in the first column of Table 1, the PW group recalled approximately the same number of major idea units as the WP group, $t(28) = -0.519$, $p = ns$. Apparently, the presentations were effective in helping both groups to learn more than 50% of the major idea units on average.

The major research question addressed in Experiment 1 concerned whether learners in the PW group learned the material more deeply than did learners in the WP group, as indicated by superior performance on the transfer test. As shown in the third column of Table 1, the PW group produced significantly more solutions on the transfer test than the WP group did, $t(28) = 2.877$, $p < .01$. This pattern of results is consistent with cognitive load theory, in which the progression from part to whole places less unnecessary load on working memory than the progression from whole to part. Learners who experience less cognitive load are better able to mentally organize the presented material into a cause-and-effect chain and to mentally relate the material with relevant prior knowledge. Thus, as predicted, this deeper level of understanding by the PW group was reflected in superior performance on tests of problem-solving transfer.

If the transition from part to whole represents an increase in perceived cognitive load, then the difficulty rating should have increased from the first to the second presentation for the PW group. If the transition from whole to part represents a decrease in perceived cognitive load, then the difficulty rating should have decreased for the WP group. As predicted, the mean rating increased from 2.00 to 2.13 for the PW group and decreased from 2.20 to 1.53 for the WP group. An analysis of variance (ANOVA) with group as a between-subjects factor and time of rating as a within-subjects factor revealed no significant effect for group, $F(1, 28) = 0.22$, $MSE = 2.65$, $p = ns$; a marginal effect for time of rating, $F(1, 28) = 3.96$, $MSE = .27$, $p < .06$; and a significant interaction between group and time of rating, $F(1, 28) = 8.92$, $MSE = .27$, $p < .01$. The interaction between group and time of rating suggests that the pattern of results across the rating periods was different for the two groups. This pattern is reflected in a significant difference in the rating change from the first to the second presentation between the groups, with a mean increase of 0.13 for the PW group and a mean decrease of 0.67 for the WP group, $t(28) = 2.987$, $p < .01$. These data, which are

Table 1
Mean Retention, Transfer, and Rating Change Scores for Each Group in Experiments 1 and 2

	Retention		Transfer		Rating change	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Experiment 1						
PW	4.60	2.06	6.13*	2.39	0.13*	0.83
WP	4.93	1.39	3.80	2.04	−0.67	0.16
Experiment 2						
PP	4.40	1.45	5.73*	2.09	−0.47	0.83
WW	4.86	1.66	3.71	1.49	−0.71	0.83

Note. PW = part–whole presentation; WP = whole–part presentation; PP = part–part presentation; WW = whole–whole presentation.
* $p < .05$.

summarized in the fifth column of Table 1, are consistent with the predictions of cognitive load theory.

In Experiment 2, both groups were exposed to identical material—two presentations of the multimedia explanation—so we expect both groups to perform at equivalent levels in remembering the major idea units on the retention test. As shown in the first column of Table 1, the PP group recalled approximately the same number of major idea units as the WW group did, $t(27) = -0.791$, $p = ns$. As in Experiment 1, the multimedia presentations were effective in helping both groups to learn, on average, more than 50% of the major idea units.

The major research question addressed in Experiment 2 concerned whether learners in the PP group learned the material more deeply than did learners in the WW group, as indicated by superior performance on the transfer test. As shown in the third column of Table 1, the PP group produced significantly more solutions on the transfer test than the WW group did, $t(27) = 2.979$, $p < .01$. This pattern of results is consistent with cognitive load theory, in which learning from two part presentations places less load on working memory than learning from two whole presentations. Learners who experience less cognitive load are better able to mentally organize the presented material into a cause-and-effect chain and to mentally relate the material with relevant prior knowledge. As predicted, this deeper level of understanding by the PP group was reflected in superior performance on tests of problem-solving transfer.

The transition from the first to the second presentation should reflect a decrease in perceived cognitive load for both groups, because both groups receive exactly the same thing in the second presentation as in the first. As predicted, the mean rating decreased from 2.47 to 2.00 for the PP group and from 2.59 to 1.88 for the WW group. An ANOVA with group as a between-subjects factor and time of rating as a within-subjects factor revealed no significant effect for group, $F(1, 27) = 0.00$, $MSE = 2.35$, $p = ns$; a significant effect for time of rating, $F(1, 27) = 14.47$, $MSE = .34$, $p < .001$; and no significant interaction between group and time of rating, $F(1, 27) = 0.64$, $MSE = .34$, $p = ns$. The lack of interaction between group and time of rating suggests that the pattern of results (i.e., moderate decreases from the first to second rating) was not different for the two groups. The mean decreases were 0.47 for the PP group and 0.71 for the WW group, $t(27) = 0.656$, $p = ns$. These data are summarized in the fifth column of Table 1 and are consistent with the predictions of cognitive load theory.

Conclusion

The Case for Part-to-Whole Presentations

On the surface, it appears that all learners received the same material—that is, two presentations of a narrated animation on lightning formation. An information-delivery view of educational technology predicts that the groups should perform about the same on tests about the material because all groups received identical information. In our two experiments, however, this prediction was contradicted by the results: The PW group performed better on the transfer test than the WP group did, and the PP group performed better on the transfer test than the WW group did. Clearly, there is more to multimedia learning than simply receiving information that is delivered by a computer.

Overall, we found that incorporating a modest amount of interactivity can promote deeper learning from a multimedia explanation if it is done in a theory-based way. Instead of the conventional whole-then-part arrangement (Kroehnert, 1995), cognitive load theory favors a part-then-whole arrangement (or a part-then-part arrangement over a whole-then-whole arrangement). Inserting interactivity per se did not improve learning. For example, both the PW and WP groups involved identical amounts of interactivity, yet the PW group learned more deeply than the WP did. Rather, interactivity improved learner understanding only when it was used in a way that is consistent with how people learn (i.e., in a way that minimized cognitive load and allowed for the two-stage construction of a mental model). The results of both Experiments 1 and 2 were consistent with the predictions of cognitive load theory: The PW group performed better on the transfer test than the WP did, and the PP group performed better on the transfer test than the WW group did.

The Case for Transfer Measures

If we had focused solely on retention as our measure of learning, we would have concluded that there were no differences among our instructional groups. However, when we considered measures intended to tap deep understanding (e.g., transfer tests) we discovered a clear advantage of PW presentation over WW presentation and PP presentation over WW presentation. The research discussed in this article showed that transfer is a better measure than retention when the goal is to evaluate how well learners understand a multimedia explanation. Deep understanding is the goal of instructional design changes (e.g., PW and PP presentations) aimed at minimizing cognitive load as learners attempt to build a causal model. It is important to note that all groups performed equivalently on remembering the basic information presented in the narrated animation. Despite this, however, the PW and PP groups showed that they were much more able to use the information they had learned to solve new problems.

Implications for Cognitive Theory

The results of these experiments contribute to both cognitive load theory and a two-stage theory of mental model construction. When the goal of instruction is to help learners build a mental model of a cause-and-effect system, cognitive load is minimized when they begin by constructing component models. Then, when they seek to construct a causal model of the system based on a narrated animation, they can devote more cognitive resources to building connections among system components rather than also trying to understand how each component works. In short, these results provide a confirmation of cognitive load theory.

Implications for Instructional Design

The results of these experiments suggest that a part-to-whole presentation is effective when the goal is to promote understanding of how a cause-and-effect system works and when the learner is unfamiliar with the material. There may be other situations in which a whole-to-part presentation is more effective, such as when the goal is to promote automatic performance of a skill (Van Merrienboer, 1997) or when the goal is to promote learning of a larger academic lesson (Reigeluth, 1983, 1999). In short, our results yield a design principle that has been shown to be effective for multimedia explanations: Provide pretraining aimed at helping learners understand the behavior of each component before presenting a fast-paced, continuous explanation of how a cause-and-effect system works.

Limitations and Future Directions

This study was limited by the short-term nature of the instructional materials (i.e., they consisted of only a few minutes of concentrated instruction rather than longer term instruction), the limited genre of the instructional materials (i.e., a cause-and-effect explanation rather than other kinds of material), the immediate nature of the test (i.e., given immediately after instruction), and the nonauthentic context (i.e., as a required psychology experiment). Future research is needed to determine whether the principle of parts–whole presentation of a multimedia explanation produces deeper learning in long-term, delayed testing, authentic learning environments. In addition, the retention test consisted of a single recall item; future research could include a collection of more targeted retention items.

Finally, learners in the part presentation condition received more time overall than learners in the whole presentation condition. Therefore, it is not possible to determine whether the positive effects of the part presentation depend on being able to control the pace of presentation or on being able to have more time to study each segment. Future research is needed to determine whether slowing the presentation rate or adding fixed pauses between segments of the presentation would have the same effect as our part presentation.

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