Computers in Human Behavior 28 (2012) 1618–1625

Contents lists available at SciVerse ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

When graphics improve liking but not learning from online lessons

Eunmo Sung [a,*], Richard E. Mayer [b]

[a] Department of Education, Seoul National University, Seoul, Republic of Korea
[b] Department of Psychology, University of California, Santa Barbara, CA 93106, United States

ARTICLE INFO

Article history:
Available online 1 May 2012

Keywords:
Graphics
Seductive details
e-Learning
Web-based learning
Multimedia effect
Multimedia learning

ABSTRACT

The multimedia principle states that adding graphics to text can improve student learning (Mayer, 2009), but all graphics are not equally effective. In the present study, students studied a short online lesson on distance education that contained instructive graphics (i.e., directly relevant to the instructional goal), seductive graphics (i.e., highly interesting but not directly relevant to the instructional goal), decorative graphics (i.e., neutral but not directly relevant to the instructional goal), or no graphics. Following instruction, students who received any kind of graphic produced significantly higher satisfaction ratings than the no graphics group, indicating that adding any kind of graphic greatly improves positive feelings. However, on a recall posttest, students who received instructive graphics performed significantly better than the other three groups, indicating that the relevance of graphics affects learning outcomes. The three kinds of graphics had similar effects on affective measures but different effects on cognitive measures. Thus, the multimedia effect is qualified by a version of the coherence principle: Adding relevant graphics to words helps learning but adding irrelevant graphics does not.

1. Introduction

People learn better from words and pictures than from words alone. This is the major tenet of the multimedia principle, which has been supported in numerous experimental studies (Butcher, 2006; Mayer, 1989; Mayer & Anderson, 1991, 1992; Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Mayer & Gallini, 1990; Moreno & Mayer, 1999; Moreno & Valdez, 2005). Evidence for the multimedia principle comes from experimental comparisons showing that adding graphics to a text lesson can improve performance on a transfer posttest by more than one standard deviation (Fletcher & Tobias, 2005; Mayer, 2009).

1.1. Three types of graphics in multimedia lessons

However, all kinds of graphics may not be equally effective in promoting learning (Butcher, 2006; Hegarty, Carpenter, & Just, 1991; Hegarty & Just, 1993). For example, Table 1 summarizes three kinds of graphics that vary in their relevance and interestingness. First, instructive graphics are relevant to the instructional goal and intended to facilitate learning the essential material in the lesson, such as showing a picture of the pony express in a lesson on early correspondence study programs of distance education that relied on the development of mail delivery systems. This picture is intended to activate prior knowledge about the role of mail delivery systems in correspondence schools. Second, seductive graphics are highly interesting but not directly relevant to the lesson, such as showing a photo of a popular movie star in a lesson on the role of early mail delivery systems in correspondence study programs for distance education. The famous face may draw the learner's attention away from the essential material in the text and thereby diminish learning. Third, decorative graphics present cognitively neutral material that is not directly relevant to the essential material, such as showing a photo of a sunrise or waterfall in the same lesson on early mail delivery systems. Although the nature photo is not related to the content of the lesson, it is intended to create a pleasing tone without being overly distracting. In short, it is intended to be neutral in cognitive impact but pleasing in affective impact.

The goal of the present study is to compare the effects of adding each of these kinds of graphics to an online instructional lesson, all in a single experimental study. Although some previous studies have investigated the effects of adding instructive graphics (i.e., sometimes yielding the multimedia effect), the effects of adding interesting but irrelevant graphics (i.e., sometimes yielding the seductive details effect), or even the effects of adding decorative graphics (i.e., sometimes yielding a null effect), our goal in the present study is to combine all three conditions in a single study so we can gauge the relative impact of each. We focus on the role of three kinds of photos, because photos are widely available and often inserted within multimedia presentations, sometimes without consideration of their relevance to the instructional goal.

* Corresponding author. Tel.: +82 10 9910 0257; fax: +82 2 883 4484.
E-mail addresses: eunmo04@snu.ac.kr (E. Sung), mayer@psych.ucsb.edu (R.E. Mayer).

0747-5632/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.chb.2012.03.026

Table 1
Three types of graphics in multimedia lessons.

Type	Description	Example
Instructive	Directly relevant to the instructional goal	Photo of pony express in a lesson on early mail delivery systems
Seductive	Highly interesting but not directly relevant to the instructional goal	Photo of popular movie star in a lesson on early mail delivery systems
Decorative	Neutral but not directly relevant to the instructional goal	Photo of a waterfall in a lesson on early mail delivery systems

1.2. Theory and predictions

Table 2 is based on the theoretical idea that graphics produce motivational effects (i.e., affecting the amount of effort the learner is willing to devote to cognitive processing during learning) and cognitive effects (i.e., affecting how the learner allocates effort during learning, such as toward appropriate cognitive processing that supports the learning goal or inappropriate cognitive processing that does not support the learning goal). As shown in the first and second columns, adding any kind of graphic can improve the learner's affect for the lesson and thereby increase the learner's motivation to engage in cognitive processing. This increase in positive inclination towards the lesson is indicated by increases in learner satisfaction ratings of the lesson as compared to a no graphics group. As shown in the third and fourth columns, adding relevant graphics is predicted to direct the learner toward engaging in appropriate cognitive processing which helps learning, whereas adding seductive graphics is predicted to direct the learner toward engaging in inappropriate cognitive processing which hurts learning, and adding decorative graphics is predicted to have little effect on cognitive processing during learning and thus little effect on learning.

The three kinds of graphics summarized in Tables 1 and 2 differ in terms of their relevance to the instructional goal. *Relevance* refers to the degree to which the content of a graphic corresponds to the essential content needed to support the instructional goal (Mayer, 2011), so instructive graphics have high relevance whereas seductive and decorative graphics have low relevance. In particular, relevance refers to the degree to which relations among the elements in the text (such as a discussion of early mail delivery systems) are analogous to the relations among the elements in the graphic (such as graphic showing mail being moved from one place to another by horseback). The two low-relevance graphics also differ with respect to interestingness. *Interestingness* refers to the degree to which the graphic draws the learner's attention (Anderson, Shirey, Wilson, & Fielding, 1987; Hidi & Baird, 1988; Mayer, Griffith, Jurkowitz, & Rothman, 2008), so seductive graphics have high interestingness whereas decorative graphics have low interestingness. In short, seductive graphics are low in relevance and high in interestingness, decorative graphics are low in relevance and low in interestingness, and instructive graphics are high in relevance and may be low to high in interestingness.

For example, if the goal of a section on distance learning is to describe early mail delivery systems such as the pony express, then a photo depicting a mail carrier riding a horse is relevant because it helps to concretize the essential content of the lesson (e.g., that distance learning involves moving communications across great distances), and thereby primes appropriate cognitive processing such as attending to the relevant information, organizing it, and integrating it with relevant prior knowledge. In contrast, a photo of a famous celebrity is irrelevant because it does not draw the learner's attention towards the essential content of the lesson or foster cognitive processing that is appropriate to the learning objective. In short, seductive graphics can prevent the learner's construction of appropriate knowledge because the learner is directing cognitive processing towards irrelevant material. Finally, decorative graphics may cause the learner to waste some cognitive processing that could have been used for learning, but not as much as seductive graphics because learners are less likely to devote large amounts of attention to an uninteresting graphic.

The case for adding graphics—even irrelevant ones—to text comes from arousal theory and emotional interest theory, which hold that students learn better when they are emotionally aroused because they are energized to pay more attention overall (Dewey, 1913; Harp & Mayer, 1998; Kintsch, 1980; Weiner, 1992). Similarly, Norman's (2004) emotional interest theory holds that attractive design features can create positive emotion in the learner, which impacts learning by increasing the learners' willingness to actively engage in the learning process.

Several existing theories seek to explain the cognitive processes underlying how people learn from words and graphics, including Paivio's dual coding theory (Paivio, 1986; Sadoski & Paivio, 2001), Sweller's cognitive load theory (Sweller, 1999, 2005), and Mayer's cognitive theory of multimedia learning (Mayer, 2009). These theories are based on the idea that humans possess separate information-processing channels for processing visual materials (such as graphics) and verbal material (such as words), but possess limited capacity for processing within each channel. Meaningful learning occurs when learners engage in appropriate cognitive processing during learning, which includes attending to relevant words and pictures, organizing them, and integrating them with each other and with knowledge from long-term memory.

Aspects of these theories suggest that adding relevant graphics to text can improve learning by encouraging these appropriate cognitive processes, whereas adding attention-grabbing irrelevant graphics can hurt learning by encouraging inappropriate cognitive processing such as attending to graphics that have nothing to do with the instructional goal and organizing the lesson content around them. In short, instructive illustrations encourage germane cognitive load (or generative cognitive processing) in which the learner makes connections between corresponding portions of the graphics and the text that support the instructional goal (Mayer, 2009; Sweller, 2005). In contrast, seductive graphics do their damage by grabbing and holding the learner's limited attention, thereby creating extraneous cognitive load (or extraneous processing) for the learner—that is, cognitive processing that does not support the instructional goal (Chandler & Sweller, 1991; Mayer, 2009, 2011; Sweller, 1988, 1999, 2005)—and by disrupting

Table 2
Motivational and cognitive effects of three types of graphics in multimedia lessons.

Type	Motivational effects	Predicted satisfaction rating	Cognitive effects	Predicted learning score
Instructive	+	+	+	+
Seductive	+	+	−	−
Decorative	+	+	0	0

the coherence of the lesson and priming an inappropriate context for learning (Harp & Mayer, 1998).

Overall, this analysis of the motivational and cognitive processes for three kinds of graphics predicts that satisfaction ratings will be improved by adding any kind of graphic whereas learning outcomes will be helped by adding instructive graphics, hurt by adding seductive graphics, and somewhat unchanged by adding decorative graphics.

1.3. Literature review

There is a substantial history of research on graphics in text, which indicates that under appropriate conditions, adding certain kinds of graphics to text can improve retention of the material (Mandl & Levin, 1989; Willows & Houghton, 1987). Levin and colleagues have distinguished among types of graphics, which has inspired our taxonomy of instructive, seductive, and decorative graphics (Levin, 1989; Levin, Anglin, & Carney, 1987; Levin & Mayer, 1993; Mayer, 1993). The present study extends this work to online multimedia learning environments involving printed text and still graphics.

1.3.1. When graphics help learning

In an early review, Levie and Lentz (1982) reported that students tended to learn more from text with illustrations than from text alone, and more recent reviews have confirmed this finding (Carney & Levin, 2002). More recently, research on the multimedia effect (Fletcher & Tobias, 2005; Mayer, 2009) supports the idea that adding instructionally relevant graphics to text can improve student learning (Butcher, 2006; Mayer, 1989; Mayer & Anderson, 1991, 1992; Mayer & Gallini, 1990; Mayer et al., 1996; Moreno & Mayer, 1999; Moreno & Valdez, 2005). For example, student learning was improved when a text on how brakes work was supplemented with line drawings showing the state of the braking system before and after pressing the brake pedal (Mayer, 1989) or when a narration on how brakes work was supplemented by a simultaneous animation showing the changes in the braking system (Mayer & Anderson, 1992). Multimedia benefits accrue across a variety of instructional materials, including conceptual tasks (e.g., Hannus & Hyona, 1999), causal tasks (e.g., Mayer & Gallini, 1990), and procedural tasks (Brunye, Taylor, Rapp, & Spiro, 2006). A common thread in studies showing a multimedia effect is that the added graphics were relevant to the instructional goal, that is, the graphics helped learning when they were instructive.

1.3.2. When graphics hurt learning

Earlier research on seductive details in text has focused mainly on the effects of adding interesting but irrelevant text to a text-based lesson (Garner, Brown, Sanders, & Menke, 1992; Garner, Gillingham, & White, 1989). More recent research on the seductive illustrations effect and the coherence effect (Mayer, 2009) in multimedia lessons supports the idea that adding highly interesting but irrelevant graphics to text can hurt student learning (Harp & Mayer, 1997, 1998; Mayer, Heiser, & Lonn, 2001). For example, interspersing video segments showing a severe lightning storm hurt student learning from a computer-based narrated animation depicting the steps in how lightning storms develop (Mayer et al., 2001). Similarly, Harp and Mayer (1997, 1998) reported that inserting photos of lightning striking an airplane or an injured person struck by lightning hurt student learning from a paper-based booklet explaining the steps in how lightning storms develop. Sanchez and Wiley (2006) provided eye-tracking data showing that students with low working-memory capacity are particularly distracted by seductive graphics. A common theme in research on the seductive details effect and the coherence effect is that the added graphics were highly interesting but not directly relevant to the instructional goal of the lesson, that is, graphics hurt learning when they were seductive.

1.3.3. When graphics have no effect on learning

Finally, in some cases graphics do not appear to have much of an effect on learning. Early research by Dwyer (1967, 1968) found no difference in high-level comprehension test scores for learning with text and diagrams versus learning with text alone, although adding illustrations aided performance on some retention test measures. More recently, researchers have found a lack of image effect in multimedia learning in which adding the image of an onscreen agent to the screen does not improve learning (Atkinson, 2002; Craig, Gholson, & Driscoll, 2002; Mayer, Dow, & Mayer, 2003; Moreno, Mayer, Spires, & Lester, 2001).

Although researchers have studied the effects of adding instructive graphics to text or adding seductive graphics to text or adding decorative graphics to text, the literature does not appear to contain studies comparing all three kinds of graphics with each other in the same experiment. The present study allows us to determine the relative impact of each kind of graphic, that is, the value-added (or value-subtracted) as compared to no graphics. According to the motivational-cognitive analysis summarized in Table 2, we expect learning outcomes to be strongest for adding instructive graphics to text, weakest for adding seductive graphics to text, and intermediate results for adding decorative graphics to text.

2. Method

2.1. Participants and design

The participants were 200 university students in South Korea, ranging from freshmen to seniors. The average age was 21.99 years (SD = 1.86), and there were 120 women and 80 men. Based on a pretest, the participants' prior knowledge about distance education was low (M = 2.44 out of 5, SD = .88). The experiment employed a between-subjects design based on type of graphic, with 50 students in the instructive graphics group, 50 students in the decorative graphics group, 50 students in the seductive group, and 50 students in the no graphics group.[1]

2.2. Materials and apparatus

The paper-based measurement materials consisted of a participant questionnaire, pretest, recall test, and satisfaction questionnaire.[2] The participant questionnaire consisted of a sheet of paper that solicited demographic information concerning the participant's age, gender, year in school, and major. The pretest consisted of five multiple-choice items concerning basic knowledge of distance education, such as:

Which of the following is correct about learning based on Information Communication and Technology?

a. Various multimedia are used.
b. It is easy to look after students.
c. Interaction between the teacher and student is not possible.
d. Students mainly study with offline instruction.

[1] Half the participants in each group received 2 min to study the lesson and half received 4 min to study the lesson. We do not focus on this time limit factor in the present study because it is not directly related to the goals of this study. ANOVAs revealed that this factor did not significantly affect satisfaction ratings, but longer study time resulted in significantly higher recall test scores. Table 3 shows mean scores and SDs for each graphic group that average over both time limits.

[2] There also was a 10-item multiple choice comprehension test administered after the recall test, but it was not included in this study because of concerns that the items did not adequately test for the material in the lesson. In some cases, the questions could be answered with common knowledge rather than having to read the lesson.

Each correct answer received one point, yielding a total score of 0–5. The reliability coefficient obtained by Cronbach's alpha was 0.75, which indicates suitable reliability.

The recall test sheet contained the line, "Please write down the key concepts or ideas in the lesson. You can write down key words but if you don't remember the key words, you can write sentences explaining the meaning of the key concepts." Participants were given 5 min to record their answer. The recall test was intended to gauge the learner's memory for the presented content (i.e., key concepts concerning the history and definition of distance education). Learners received 1 point for a key concept if they wrote down a key idea either using the key words in the lesson or using words that had the same meaning, such as the idea that in distance education students and teachers are in different places or that correspondence study was an early form of distance learning or in correspondence study courses were delivered by mail. There were 25 key concepts in the lesson, so each correct answer received one point, yielding a total score of 0–25.

The satisfaction questionnaire sheet consisted of four rating items concerning the learner's feeling during learning with the web-based material. Participants were asked to rate on a 5-point scale (with 1 = *very little*, 5 = *very much*) their level of agreement with statements such as, "I enjoyed learning this material." and "I felt good when I studied this material." The satisfaction questionnaire was intended to measure learning satisfaction. The reliability coefficient obtained by Cronbach's alpha was 0.81, which indicates suitable reliability. The satisfaction questionnaire yielded a mean rating (between 1 and 5) across the four items for each participant.

There were four versions of a 3-page web-based lesson, all containing identical text describing the history and definition of distance education. The lesson contained 25 main ideas in a script of 651 words. It had two main topics, the historical development of distance education and the definition of distance education. The complete text translated into English is shown in Appendix A. As exemplified in Fig. 1, the instructive graphics version contained eight instructive graphics (such as a photo of the pony express in a part of the lesson describing the role of reliable mail delivery in the development of correspondence study), the seductive graphics version contained eight seductive graphics (such as a photo of a popular actress in a part of the lesson describing the role of reliable mail delivery in the development of correspondence study), the decorative graphics version contained eight decorative graphics (such as a photo of a sunrise over a lake or a waterfall in a part of the lesson describing the role of reliable mail delivery in the development of correspondence study), and the no graphics version contained no graphics. For each lesson there were three graphics on the first page, four graphics on the second page, and one graphic on the final page. In addition to the photos shown in Fig. 1, the instructive lesson contained vintage photos of people listening to a radio or watching a TV (for the section on the second generation of distance learning), photos of people holding smart phones or using desktop computers (for the section on the third generation of distance learning), and photos of students watching a big-screen TV of students at a remote site (for the section on the definition of distance learning); the seductive lesson contained photos of popular celebrities and posters of popular movies; the decorative lesson contained photos of flowers, plants, and clouds. All materials were in the Korean language as all participants were native speakers of Korean.

The apparatus consisted of approximately 40 Samsung desktop computer systems with 17-in. flat-panel monitors. A stopwatch was used to control learning time and the tests.

2.3. Procedure

The experiment took place in a university computer lab where students participated individually at a workstation. First, participants were randomly assigned to treatment groups and seated at a computer workstation where they were asked to sign the consent form and fill in their individual information in the participant questionnaire. Second, participants answered the pretest containing five multiple choice items at their own pace. Third, following an introduction, participants received the multimedia lesson corresponding to their treatment group. Fourth, when participants completed the lesson, they were given the satisfaction questionnaire containing four rating items to be completed at their own pace. Fifth, participants completed the recall test within a 5-min time limit, in which they were asked to write down the key ideas or to explain key sentences about the history and definition of distance learning. After completion of all tests participants were debriefed and thanked for participating.

3. Results

3.1. Do the groups differ on basic demographic characteristics?

A preliminary issue concerns whether the groups differed on basic demographic characteristics in spite of random assignment of participants to groups. Based on analysis of variance (ANOVA) or chi-square tests with $p < .05$, the groups did not differ significantly on age, gender, and year in college. A one-way ANOVA comparing the groups on prior knowledge score, with Tukey post hoc tests of pair-wise comparisons as warranted (with $p < .05$), revealed there were no significant differences among the groups, and hence no indication that the groups differed in prior knowledge of distance education.

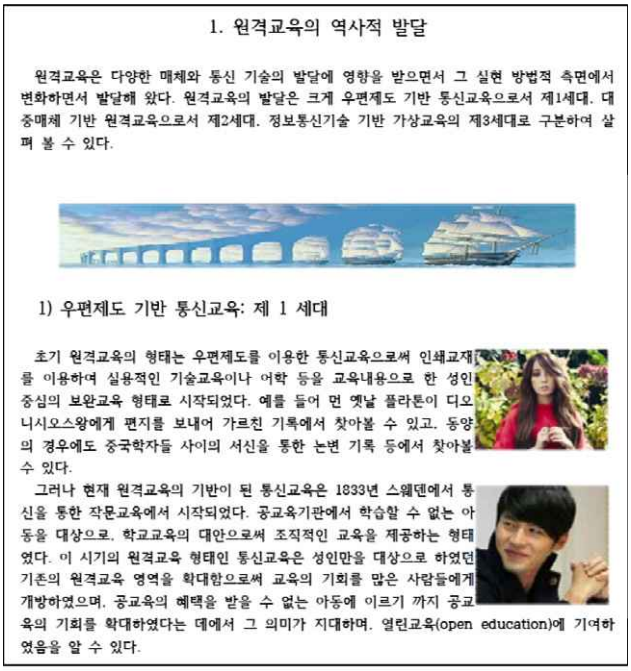
3.2. Does type of graphic affect recall test score?

The primary issue concerns how adding each kind of graphic affects learning, as measured by recall of the 25 key ideas in the lesson. The top row of Table 3 shows the mean recall score (out of 25) for each of the four graphics groups. Effect size was computed using Cohen's *d* (Cohen, 1988). Consistent with predictions, a one-way ANOVA showed that the four graphics groups differed significantly on recall test score, $F(3, 196) = 11.55$, $MSE = 15.01$, $p < .001$, with the instructive graphics group performing much better than the other three groups. Post-hoc Tukey tests were conducted for each pair-wise comparison with alpha set at .05. The Tukey tests revealed that the instructive graphics group significantly outperformed each of the other three groups (at $p < .05$), which did not differ significantly from each other. Compared to the no graphics group, the instructive graphics group produced a medium-to-large positive effect size ($d = 0.79$), the seductive graphics group produced a small-to-medium negative effect size ($d = -0.38$), and the decorative graphics group produced a negligible effect size ($d = 0.14$). Overall, the results are generally consistent with the predictions of the motivational-cognitive theory as summarized in Table 2. Although the difference between the seductive group and the no graphics group did not reach significance, a *t*-test produced a marginal negative effect [$t(98) = 1.923$, $p = .0574$], the negative effect size is in the small-to-medium range, and the best-fitting model assumes a negative effect for the seductive group.

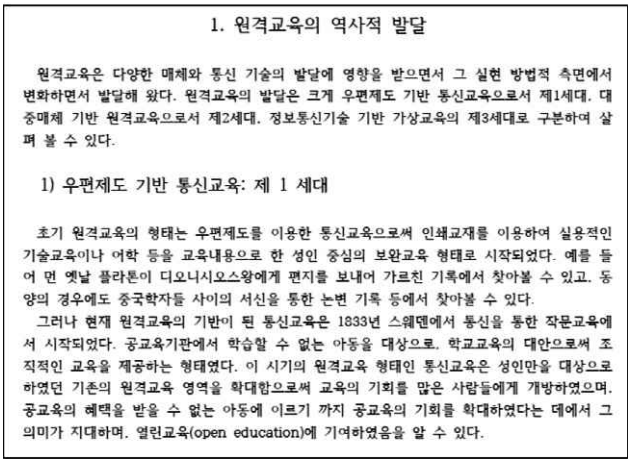
Table 4 shows four models based on Pearson correlations based solely on the presence of photos (interest model), the relevance of photos (relevance model), both, or both with double weighting for relevance. Models based on Pearson correlations indicated that a

Instructive graphics with text

Decorative graphics with text



Seductive graphics with text



Text Only

Fig. 1. Example frames from multimedia learning lesson on distance education for each of four groups.

Table 3
Mean recall test scores and satisfaction ratings (and *SD*s) for four groups.

Measure	Type of graphics							
	Instructive		Decorative		Seductive		No graphics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Recall score (25)	11.08*	4.25	8.46	4.32	6.66	2.72	7.90	3.66
Satisfaction rating (5)	3.83*	0.70	3.86*	0.45	3.57*	0.60	2.95	0.73

* Score or rating is significantly greater than the no graphics group at $p < .05$.

model based solely on the relevance of photos (1, 0, −1, 0 for the instructive, decorative, seductive, and no graphics, respectively) produced a strong, significant correlation with $r = .97$, $p = .031$. In contrast, a model based solely on the presence of photos (1, 1, 1, 0 for the instructive, decorative, seductive, and no graphics, respectively) did not produce a significant correlation, $r = .22$,

Table 4
Four models and model fits for mean recall score and mean satisfaction rating.

Type of photo	Type of model			
	Interest	Relevance	Both	Both (weighted)
Instructional	1	1	2	3
Decorative	1	0	1	1
Seductive	1	−1	0	−1
None	0	0	0	0

Measure	Fit of model (r)			
	Interest	Relevance	Both	Both (weighted)
Recall score (Learning)	.22	.97*	.94	.99*
Satisfaction rating (Liking)	.95*	.25	.52	.71

* Correlation (r) is significant at $p < .05$.

$p = .776$. However, the best fitting model included weights both for relevance of photos (given double weight) and for the presence of photos (3, 1, −1, 0 for instructive, decorative, seductive, and no graphics, respectively), with $r = .99$, $p = .008$. These analyses are consistent with the predictions in the right columns of Table 2, in which relevance of photos is strongly related to recall test performance. Unexpectedly, however, the best fitting model also included presence of photos, suggesting that having graphics on the page may add modestly to learning outcomes (in addition to the relevance of photos).

3.3. Does type of graphic affect satisfaction ratings?

The second row of Table 3 shows the mean satisfaction rating (on a 5-point scale) for each group. As predicted, there was a significant main effect on satisfaction rating for type of graphic, $F(3, 196) = 22.31$, $MSE = 0.40$, $p < .001$, in which each of the three graphics groups scored higher on satisfaction than the no graphics group. Post-hoc Tukey tests (with $p < .05$) revealed that the instructive graphics group ($d = 1.21$), the decorative graphics group ($d = 1.25$), and the seductive graphics group ($d = 0.85$) each significantly outperformed the no graphics group (at $p < .05$), but did not differ significantly from each other. Consistent with the predictions in Table 2, students liked having graphics added to their online lessons—but liking did not always translate into learning.

As shown in Table 4, models based on Pearson correlations indicated that a model based solely on the presence of photos (1, 1, 1, 0 for the instructive, decorative, seductive, and no graphics, respectively) produced a significant correlation, $r = .95$, $p = .049$. In contrast, a model based solely on the relevance of photos (1, 0, −1, 0 for the instructive, decorative, seductive, and no graphics, respectively) did not produce a significant correlation with $r = .25$, $p = .749$. Unlike the analysis involving recall data, a model including weights both for relevance of photos (given double weight) and for the presence of photos (3, 1, −1, 0 for instructive, decorative, seductive, and no graphics, respectively), did not produce a significant correlation, $r = .52$, $p = .481$. These analyses are consistent with the predictions in the left columns of Table 2, in which presence of a photo is best correlate of satisfaction rating.

4. Discussion

4.1. Empirical contributions

The primary findings are: (1) in comparing the instructive graphics group and the no graphics group, there is a multimedia effect in which adding instructive graphics greatly improves recall test performance ($d = 0.79$), (2) in comparing the seductive graphics group with the no graphics group, there is a marginal seductive details effect in which adding seductive graphics hurts recall test performance ($d = -0.38$), and (3) in comparing the decorative graphics group with the no graphics group, recall test performance is not significantly different ($d = 0.13$). Although these results are consistent with prior research on the multimedia effect and coherence effect, they advance the field by showing how the effects of different kinds of illustrations compare with one another within the same experiment. Overall, relevant graphics are more effective in promoting learning than irrelevant graphics.

The secondary findings are that satisfaction ratings were higher for lessons that contained any kind of graphics than for lessons with no graphics. These results show that liking (as measured by satisfaction ratings) does not automatically translate into learning (as measured by recall tests). Although students liked all three kinds of graphics equally well, different kinds of graphics had quite different effects on learning outcome measures.

4.2. Theoretical contributions

The results concerning the differential effects of different kinds of graphics on learning outcomes support theories about cognitive processes in multimedia learning. In short, the results support aspects of dual coding theory, cognitive load theory, and the cognitive theory of multimedia learning by confirming the prediction that instructive graphics would be more effective than seductive graphics (with decorative graphics in between). Although any type of graphic can increase positive affect, which increases a willingness to engage in learning, learners are more likely to engage in instructionally appropriate cognitive processing when they receive instructive graphics which draw their attention toward the essential content than when they receive seductive graphics which draw their attention away from the essential content.

The results concerning the positive effects of all kinds of graphics on satisfaction ratings support theories about motivational processes in multimedia learning. In short, the results support aspects of arousal theory, emotional interest theory, and emotional design theory by confirming the prediction that adding graphics would increase learners' positive assessment of the learning situation.

4.3. Practical contributions

The main practical contribution of this study is to confirm the coherence principle (Mayer, 2009) particularly with respect to graphics, that is, people learn better from multimedia lessons when the graphics are relevant rather than irrelevant to the instructional goal. In short, this study serves to modify the multimedia principle, by emphasizing the need to incorporate educationally relevant graphics into a lesson. This principle also serves to modify the seductive details principle, by emphasizing the need to use interesting graphics that are specifically relevant to supporting the educational goal.

If the main goal of a lesson is to promote enjoyment, then adding nearly any kind of graphics may be appropriate. Enjoyment may be an important objective because enjoyable graphics may produce motivational benefits that keep the learner willing to continue. In the present study, people were more satisfied when they learned from multimedia lessons containing images than text only lessons perhaps because human beings are visually oriented (Dwyer, 2007; Norman, 2004) and images create arousal (Harp & Mayer, 1997, 1998).

4.4. Methodological contributions

A useful methodological contribution of the present study is to compare the effects of various types of graphics within a single study. We used a between subjects design to avoid carry-over

effects. The between subjects design represents an advance over comparing the effects of different types of graphics across different published experiments, because all learners in the present study received the same instructional text and took the same test.

4.5. Limitations and future directions

The lessons used in this study were short, the material was simple, the test was immediate, the learners were college students, and only one lesson was involved. Additional research is needed to determine whether the results can be replicated under different conditions, including whether the present effects apply beyond learning historical facts and definitions.

Although the predicted pattern of results was obtained for the recall test and the satisfaction ratings, more research is needed to determine when the positive motivating effects of having graphics outweigh the negative cognitive effects of directing attention away from the essential material in the lesson. In particular, it would be useful to include a transfer test to better tap learner understanding of the material.

A strong version of the seductive illustrations effect occurs when interesting but irrelevant illustrations in a multimedia lesson (e.g., as in the seductive graphics group) hurt performance on measures of learning outcome, whereas a weak version of the seductive illustrations effect occurs when interesting but irrelevant illustrations in a multimedia lesson do not help learning. Although the results concerning recall test performance of the seductive graphics group reflect the weak version of the seductive illustrations effect, future research is needed to pinpoint the factors that lead to the strong or weak versions.

Finally, we did not have a direct measure of the relevance or interestingness of the graphics, or direct measures of perceptual processing of the graphics during learning. More research is needed to calibrate the relevance and interestingness of the graphics used in e-lessons, perhaps using independent learner ratings, and to document the learner's attention to the graphics, perhaps using eye-tracking methodology.

In summary, the educational effectiveness of e-lessons can be improved by inserting graphics that are relevant rather than irrelevant to the instructional goal.

Appendix A. Full text of e-lesson in distance learning (translated from Korean)

A.1. The historical context of distance education

Distance education has evolved through several historical generations. The first generation was when the medium of communication was text and instruction was by postal correspondence. The second generation was teaching by means of broadcast radio and television. Finally, the most recent generation of distance education involves teaching and learning based on Internet technologies.

A.1.1. First generation: a correspondence study

The history of distance education begins with courses of instruction that were delivered by mail that usually was called correspondence study. Beginning in the early 1880s, people who wanted to study at home or at work could, for the first time, obtain instruction from a distance teacher. This was because of the invention of new technology—cheap and reliable postal services, resulting largely from the spread of the postal mailing system. Corresponding through the mail was first used for higher education courses by The Chautauqua Correspondence College in 1881. At the same time, using mail to deliver teaching occurred in other countries such as Great Britain, France, and Germany.

Correspondence courses were usually in vocational subjects, and took advantage of the new rural free delivery of mail to deliver course material to students who were located in rural or remote areas that did not have geographical access to educational institutions. Students worked independently on course material and interaction between teacher and student was limited to one-way communications.

A.1.2. Second generation: broadcasting-based distance education

As new media emerged such as radio and television, these new technologies were integrated into distance education delivery methods. When radio and television appeared as a delivery technology for education, many educators in university extension departments reacted with optimism and enthusiasm. Based on those, in 1967 the British Open University was established by the British Government as a revolutionary new educational institution. The Open University marked a significant development in the delivery of distance education by using radio and television to provide access to higher education for the adult population. The UKOU, which has both quality and cost effectiveness, has been widely emulated in other countries.

Distance education by means of educational radio and television provided educational opportunity to any adult who wanted such education regardless of geographic location. In addition, these types of delivery methods and media continue to be used, offering a mixed-media approach to distance learning technologies.

A.1.3. Third generation: computer and internet-based virtual classes

The use of computer networking systems (i.e., World Wide Web, Internet, satellites, two-way interactive video, mobile technology, etc.) allowed interaction between teacher and learner, learner and learner, learner and content at any time, any distance, and any place. In other words, computer and Internet technologies led to a worldwide explosion of interest and activity in distance education, with new organizational structures, collaborative constructivist learning methods, and the convergence of text, audio, and video on a single communications platform.

Just as each previous generations of technology—that is, correspondence, broadcast radio and TV—produced its particular form of distance learning organization, the spread of Internet technology stimulated new thinking about how to organize distance teaching. This has been the case in established single mode open universities and correspondence schools, but also especially single mode institutions and those single-mode, face-to-face teaching institutions that never before considered distance education but are now converting to dual mode status. New technology has also led to the emergence of new forms of single mode, purely electronic universities and to new combinations and collaborations among institutions of all types.

A.2. definition of distance education

The basic idea of distance education is simple: students and teachers are in different places for all or most of the time that they learn and teach. Being in different places, they depend on some kind of technology to deliver information and give them a way of interacting with each other. To capture the multidimensional nature of this field, the generic definition of distance education is as following:

> Distance education is planned learning that normally occurs in a different place from teaching, requiring special course design and instruction techniques, communication through various technologies, and special organizational and administrative arrangements.

In order to explore this definition, Keegan analyzed each of the earlier definitions of distance education which incorporated five characteristics.

- The quasi-permanent separation of teacher and learner throughout the length of the learning process (this distinguishes it from conventional face-to-face education).
- The influence of an educational organization both in the planning and preparation of learning materials and in the provision of student support services (this distinguishes it from private study and teach-yourself programs).
- The use of technical media—print, audio, video, or computer—to unite teacher and learner and carry the content of the course.
- The provision of two-way communication so that the student may benefit from or even initiate dialogue (this distinguishes it from other uses of technology in education).
- The quasi-permanent absence of the learning group throughout the length of the learning process so that people are usually taught as individuals rather than in groups, with the possibility of occasional meetings, either face-to-face or by electronic means, for both didactic and socialization purposes.

References

Anderson, R. C., Shirey, L. L., Wilson, P. T., & Fielding, L. G. (1987). Interestingness of children's reading material. In R. E. Snow & M. J. Farr (Eds.), *Aptitude, learning, and instruction. Conative and affective process analysis (Vol. 3)* (pp. 287–299). Hillsdale, NJ: Erlbaum.

Atkinson, R. K. (2002). Optimizing learning from examples using animated pedagogical agents. *Journal of Educational Psychology, 94*, 416–427.

Brunye, T. T., Taylor, H. A., Rapp, D. N., & Spiro, A. B. (2006). Learning procedures: The role of working memory in multimedia learning experiences. *Applied Cognitive Psychology, 20*, 917–940.

Butcher, K. R. (2006). Learning from text with diagrams: Promoting mental model development and inference generation. *Journal of Educational Psychology, 98*, 182–197.

Carney, R. N., & Levin, J. R. (2002). Pictorial illustrations still improve students' learning from text. *Educational Psychology Review, 98*, 182–197.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction, 8*, 293–332.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Craig, S. D., Gholson, B., & Driscoll, D. M. (2002). Animated pedagogical agents in multimedia educational environments: Effects of agent properties, picture features, and redundancy. *Journal of Educational Psychology, 94*, 428–434.

Dewey, J. (1913). *Interest and effort in education*. Cambridge, MA: Houghton Mifflin.

Dwyer, F. M. (1967). The relative effectiveness of varied visual illustrations in complementing programmed instruction. *Journal of Experimental Education, 36*, 34–42.

Dwyer, F. M. (1968). The effectiveness of visual illustrations used to complement programmed instruction. *Journal of Psychology, 70*, 157–162.

Dwyer, F. M. (2007). The program of systematic evaluation (PSE): Evaluating the effects of multimedia instruction 1965–2007. *Educational Technology, 47*(5), 41–45.

Fletcher, J. D., & Tobias, S. (2005). The multimedia principle. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 117–134). New York: Cambridge University Press.

Garner, R., Brown, R., Sanders, S., & Menke, D. (1992). "Seductive details" and learning from text. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 239–254). Hillsdale, NJ: Erlbaum.

Garner, R., Gillingham, M., & White, C. (1989). Effects of "seductive details" on macroprocessing and microprocessing in adults and children. *Cognition and Instruction, 6*, 41–57.

Hannus, M., & Hyona, J. (1999). Utilization of illustrations during learning of science textbook passages among low- and high-ability children. *Contemporary Educational Psychology, 24*, 95–123.

Harp, S. F., & Mayer, R. E. (1997). The role of interest in learning from scientific text and graphics: On the distinction between emotional and cognitive interest. *Journal of Educational Psychology, 89*, 92–102.

Harp, S. F., & Mayer, R. E. (1998). How seductive details do their damage: A theory of cognitive interest in science learning. *Journal of Educational Psychology, 90*, 414–434.

Hegarty, M., Carpenter, P. A., & Just, M. A. (1991). Diagrams in the comprehension of scientific text. In R. Barr, M. Kamil, P. B. Mosenthal, & P. D. Pearson (Eds.). *Handbook of reading research* (Vol. 2, pp. 641–668). New York: Longman.

Hegarty, M., & Just, M. A. (1993). Constructing mental models of machines from text and diagrams. *Journal of Memory and Language, 32*, 717–742.

Hidi, S., & Baird, W. (1988). Strategies for increasing text-based interest and students' recall of expository texts. *Reading Research Quarterly, 23*, 465–483.

Kintsch, W. (1980). Learning from text, levels of comprehension, or: Why anyone would read a story anyway. *Poetics, 9*, 87–98.

Levie, W. H., & Lentz, R. (1982). Effects of text graphic: A review of research. *Educational Communication and Technology Journal, 30*(4), 195–232.

Levin, J. R., Anglin, G. J., & Carney, R. N. (1987). On empirically validating functions of pictures in prose. In D. M. Willows & H. A. Houghton (Eds.), *The psychology of illustration. Basic research* (Vol. 1, pp. 51–85). New York: Springer-Verlag.

Levin, J. R. (1989). A transfer-appropriate-processing perspective of pictures in prose. In H. Mandl & J. R. Levin (Eds.), *Knowledge acquisition from text and pictures* (pp. 83–100). Amsterdam: Elsevier.

Levin, J. R., & Mayer, R. E. (1993). Understanding illustrations in text. In B. Britton, A. Woodward, & M. Binkley (Eds.), *Learning from textbooks: Theory and practice* (pp. 95–113). Hillsdale, NJ: Erlbaum.

Mandl, H., & Levin, J. R. (Eds.). (1989). *Knowledge acquisition from text and pictures*. Amsterdam: North-Holland.

Mayer, R. E. (1989). Systematic thinking fostered by illustrations in scientific text. *Journal of Educational Psychology, 81*, 240–246.

Mayer, R. E. (1993). Illustrations that instruct. In R. Glaser (Ed.). *Advances in instructional psychology* (Vol. 4, pp. 253–284). Hillsdale, NJ: Erlbaum.

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). New York: Cambridge University Press.

Mayer, R. E. (2011). *Applying the science of learning*. Upper Saddle River, NJ: Pearson.

Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of a dual-coding hypothesis. *Journal of Educational Psychology, 83*, 484–490.

Mayer, R. E., & Anderson, R. B. (1992). The instructive animation: Helping students build connections between words and pictures in multimedia learning. *Journal of Educational Psychology, 84*, 444–452.

Mayer, R. E., Bove, W., Bryman, A., Mars, R., & Tapangco, L. (1996). When less is more: Meaningful learning from visual and verbal summaries of science textbook lessons. *Journal of Educational Psychology, 88*, 64–73.

Mayer, R. E., Dow, G. T., & Mayer, S. (2003). Multimedia learning in an interactive self-explaining environment: What works in the design of agent-based microworlds? *Journal of Educational Psychology, 95*, 806–813.

Mayer, R. E., & Gallini, J. K. (1990). When is an illustration worth ten thousand words? *Journal of Educational Psychology, 82*, 715–726.

Mayer, R. E., Griffith, E., Jurkowitz, I., & Rothman, D. (2008). Increased interestingness of extraneous details leads to decreased learning. *Journal of Experimental Psychology: Applied, 14*, 329–339.

Mayer, R. E., Heiser, H., & Lonn, S. (2001). Cognitive constraints on multimedia learning: When presenting more material results in less understanding. *Journal of Educational Psychology, 93*, 187–198.

Moreno, R., & Mayer, R. E. (1999). Multimedia-supported metaphors for meaning making in mathematics. *Cognition and Instruction, 17*, 215–248.

Moreno, R., Mayer, R. E., Spires, H. A., & Lester, J. C. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? *Cognition and Instruction, 19*, 177–213.

Moreno, R., & Valdez, R. (2005). Cognitive load and learning effects of having students organize pictures and words in multimedia environments: The role of student interactivity and feedback. *Educational Technology Research and Development, 53*, 35–45.

Norman, D. (2004). *Emotional design*. New York: Basic Books.

Paivio, A. (1986). *Mental representation: A dual coding approach*. England: Oxford Univ. Press.

Sadoski, M., & Paivio, A. (2001). *Imagery and text: A dual coding theory of reading and writing*. Hillsdale, NJ: Erlbaum.

Sanchez, C. A., & Wiley, J. (2006). An examination of the seductive details effect in terms of working memory capacity. *Memory & Cognition, 34*, 344–355.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*, 257–285.

Sweller, J. (1999). *Instructional design in technical areas*. Camberwell, Australia: ACER Press.

Sweller, J. (2005). Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 19–30). New York: Cambridge University Press.

Weiner, B. (1992). Motivation. In M. Alkin (Ed.), *Encyclopedia of educational research* (6th ed., pp. 860–865). New York: Macmillan.

Willows, D. M., & Houghton, H. A. (Eds.). (1987). *The psychology of illustration. Basic research (Vol. 1)*. New York: Springer-Verlag.