Education Tech Research Dev (2018) 66:563–577
https://doi.org/10.1007/s11423-017-9554-x

RESEARCH ARTICLE

Applying the segmenting principle to online geography slideshow lessons

Richard E. Mayer[1] · Jeffrey T. Howarth[2] · Michelle Kaplan[1] · Sara Hanna[1]

Published online: 12 December 2017

Abstract Multimedia design principles were applied to an online geography slideshow on geographic information systems (GIS) intended for college students taking an introductory course. In a 2 (segment vs. non-segmented) × 2 (redundant vs. non-redundant) between-subjects design, the base lesson (non-segmented condition) provided a worked example of how to solve an extended GIS problem, consisting of 12 slides with each showing graphics on the left side with corresponding text in the right side. Students progressed through the lesson by pressing the right arrow key to move to the next slide. The segmented lesson (segmented condition) consisted of the same slides, but the material on each slide was presented sequentially in which pressing the right arrow key added a single graphic and/or corresponding text explaining each of 3 or 4 major steps. For both versions, some students received additional narration that was identical to the printed text (redundant condition) or no additional narration (non-redundant condition). On a subsequent transfer test, the results showed a *segmenting effect* in which students performed significantly better with segmented than non-segmented versions of the lesson ($d = 0.34$), and this pattern was the same whether narration was added or not, yielding no interaction between segmenting and redundancy and no significant effect for redundancy. This work extends the segmenting principle to a new medium, domain, and segment size.

✉ Richard E. Mayer
mayer@psych.ucsb.edu

Jeffrey T. Howarth
jhowarth@middlebury.edu

Michelle Kaplan
micakap00@gmail.com

Sara Hanna
shannagezef@aol.com

[1] Department of Psychological and Brain Sciences, University of California, Santa Barbara, Santa Barbara, CA 93106, USA

[2] Department of Geography, Middlebury College, Middlebury, VT 05753, USA

Keywords Multimedia learning · Segmenting principle · Redundancy principle · Online learning · Instructional design · Computer-based instruction · Slideshow

Introduction

Objective

A common practice in introductory-level college courses is to assign online lessons covering core content to be studied outside of class as a way of implementing blended instruction (Clark and Mayer 2016). The present study involves an online multimedia lesson on how a geographic information system (GIS) works, which would typically be covered in an introductory geography course. The lesson presents an extended worked example demonstrating how to use four different operations through a series of 12 PowerPoint slides, each with graphics and corresponding printed text placed to the right of the graphics. The learner controls the pace of the lesson by pressing an arrow key to go on to the next slide. The goal of the present study is to examine the effectiveness of adding two instructional design features to an online multimedia slideshow: (1) segmenting, in which each time the learner presses the arrow key another portion of the slide appears (typically with 4–8 portions per slide) rather than having an entire slide appear all at once, and (2) redundancy, in which a voice is added that reads aloud the printed text. A justification for the study is that improving student learning from online resources is an important aspect of making blended instruction effective.

Our main focus is on the *segmenting principle*, which states that "people learn better when a multimedia lesson is presented in user-paced segments than as a continuous unit" (Mayer 2009, p. 268), and which is based mainly on lessons involving narrated animations. This work advances research and theory in computer-based instructional design by implementing the segmenting principle in a novel way using a slideshow format rather than a narrated animation (i.e., by allowing learners to add sections to the slide screen sequentially rather than presenting it all at once), by extending the conceptualization of segments to coherent chunks in a procedure (i.e., a meaningful step in a process consisting of an illustration and text on approximately 1/3 or 1/4 of the screen), by using new materials and tests (i.e., an extended worked examine in the domain of solving a problem in GIS), by using material that fits within the curriculum of a college course using blended learning methods (i.e., material from an existing college course in geography), and by determining if the segmenting effect is robust enough to be found both when narration is added to illustration and text (redundant condition) and when it is not (non-redundant condition).

Slideshows are a commonly used technology for education and training, including computer-based lessons, with millions of slideshows presented each day, but work is needed to identify research-based principles for their design (Atkinson 2008; Duarte 2008; Kosslyn, 2007; Reynolds 2008). The impact of slideshows is so great that Duarte (2008, p. xv) refers to the launching of PowerPoint in 1987 as "the click heard round the world," yet 30 years later researchers are still in the process of examining and testing how best to present effective slideshows in light of what we know about the science of learning (Mayer 2011).

The case for segmenting

Based on the cognitive theory of multimedia learning (Mayer 2009, 2014) and cognitive load theory (Brunken et al. 2003; Plass et al. 2010; Sweller et al. 2011) the theoretical rationale for segmenting is to manage essential processing—cognitive processing that is needed to mentally represent the essential material—by reducing demands on working memory. In the present study, students in the segmented group receive an illustration and text corresponding to one major step in a process. Thus, learners in the segmented group can digest the material one segment at a time, so they can mentally represent what happens in one major step before moving on to the next one. The major prediction tested in the present study is that adding segmenting to an online slideshow will lead to improvements on tests of learning outcome. A secondary prediction is that this segmenting effect for learning outcome will be equivalent both when redundant narration is added and when it is not, indicating the robustness of the segment effect.

A recent review of research on segmenting shows that in 10 of 10 published experimental comparisons students performed better on transfer tests with a segmented version of a multimedia lesson rather than with a continuous version, with a median effect size of $d = 0.79$ (Mayer and Pilegard 2014). For example, in a study by Mayer and Chandler (2001), students viewed a 140-s narrated animation on lightning or viewed the same lesson broken down in 16 segments–each about 8–10 s long with about one sentence of narration–and clicked on a CONTINUE button to go on to the next segment. The segmented group outscored the continuous group by more than one standard deviation on a transfer test, even though both groups received identical material. In a study by Mayer et al. (2003), students viewed a narrated animation on how an electric motor works explained by an onscreen agent named Dr. Phyz or clicked on a series questions, each of which presented a segment of the same narrated animation. Students who received the narrated animation segment-by-segment performed better on a subsequent transfer test than the students who received a continuous presentation of the identical material (with effect sizes greater than .8 across two experiments).

Moreno (2007) asked prospective teachers to view a video lesson or an animated lesson that depicted expert teaching skills. For some students, the lesson was broken into seven segments, with the student clicking a button to continue on to the next segment. Across both experiments, the segmented group outperformed the continuous group on a transfer test (with effects sizes greater than .5).

Hasler et al. (2007) asked elementary school children to view a narrated animation on the causes of day and night. A group that received the lesson as leaner-paced segments performed better on a subsequent transfer test than a group that received a continuous presentation (with an effect size greater than .8).

Boucheix and Schneider (2009) presented college students with a continuous animation demonstrating how a pulley system works or the same animation broken down into steps with pacing under learner control. The segmented group outperformed the continuous group on a transfer test (with an effect size of .3). Boucheix and Guignard (2005) reported similar results for a study involving gears.

Concerning boundary conditions, Lusk et al. (2009) found segmenting a multimedia lesson on historical inquiry improved transfer performance for students with low working memory capacity but not for students with high working memory capacity. Stiller et al. (2009) found that college students who viewed a segmented lesson on the human eye outperformed those viewing a continuous lesson on a transfer test when the words were spoken but much less so when the words were printed on the screen. Hassanabadi et al. (2011) reported a similar pattern in which the segmenting effect was stronger when words were spoken than printed for a lesson on lightning given to middle school students. Furthermore, Ayres (2006) and Spanjers et al. (2011) provide some preliminary evidence that segmenting effects are stronger for low-knowledge students than for high-knowledge students who are learning from worked examples in mathematics, so in the present study we focus on non-geography students who are likely to find the material to be unfamiliar and difficult. Additionally, breaking complex data graphs into parts improves performance in geoscience (Mautone and Mayer 2007) and chemistry (Lee et al. 2006), so in the present study we also break the graphics into segments for the segmenting treatment in addition to breaking the text into segments.

Overall, the most common way of implementing segmenting is to take a continuous narrated animation or video and break it into meaningful segments for which the learner can click on a button to go to the next segment. Although this form of segmenting based on animation and video has been shown to be highly effective in improving transfer test performance across 10 experiments (Mayer and Pilegard 2014), the present study extends the conceptualization of segmenting to a multimedia slideshow format. Specifically, we take a static slide that is full of graphics and text about how to use a geographic information system (GIS) such as shown in the last frame of Fig. 1 for the DISTANCE tool, and break it down into several segments each describing a key step or sub-step in the process, such as shown in the progression of the 8 slides in Fig. 1. We start with the first segment at the top of the slide (showing an illustration on the left and some text on the right); then the student clicks on the arrow key to see some addition text which appears to the right of the illustration or to see the next segment which is added to screen just below the first segment. Each of the eight frames shows what the student sees after pressing a right arrow key in the section of the lesson showing how the DISTANCE tool works.

This learner-controlled approach is different from the typical teacher-controlled face-to-face slideshow in which bullet points are added one by one to the screen, because (1) our approach allows for learner control of pacing rather than teacher control of pacing, and (2) our approach involves sequential presentation of meaningful, conceptually coherent segments rather than fragmented factoids. In our lesson, seeing the entire slide at once can be overwhelming, so we use segmenting as a way to encourage learners to digest one complete step in the process before moving on to the next one. In short, this study examines whether the segmenting effect established with narrated animation and video extends to a new format–learner-controlled segmenting of a slideshow. None of the reviewed studies involved learner-controlled slideshow format or a worked example in the geography domain as in the present study, so the present study allows an extension of the segmenting principle to a new format and domain. This study helps to determine whether breaking content about a procedure into meaningful steps and allowing students to control the pacing of the segments works as an instructional design feature when the material is presented as a slideshow. The same theory that predicts the segmenting effect with narrated animation and video also applies here but to date the predictions have not been tested in a controlled experiment.

The case against redundancy

In the present study, we incorporate redundancy by adding a male voice that reads the text printed on the screen. This is consistent with the definition of verbal redundancy as presenting identical spoken and printed text simultaneously (Mayer and Fiorella 2014). We

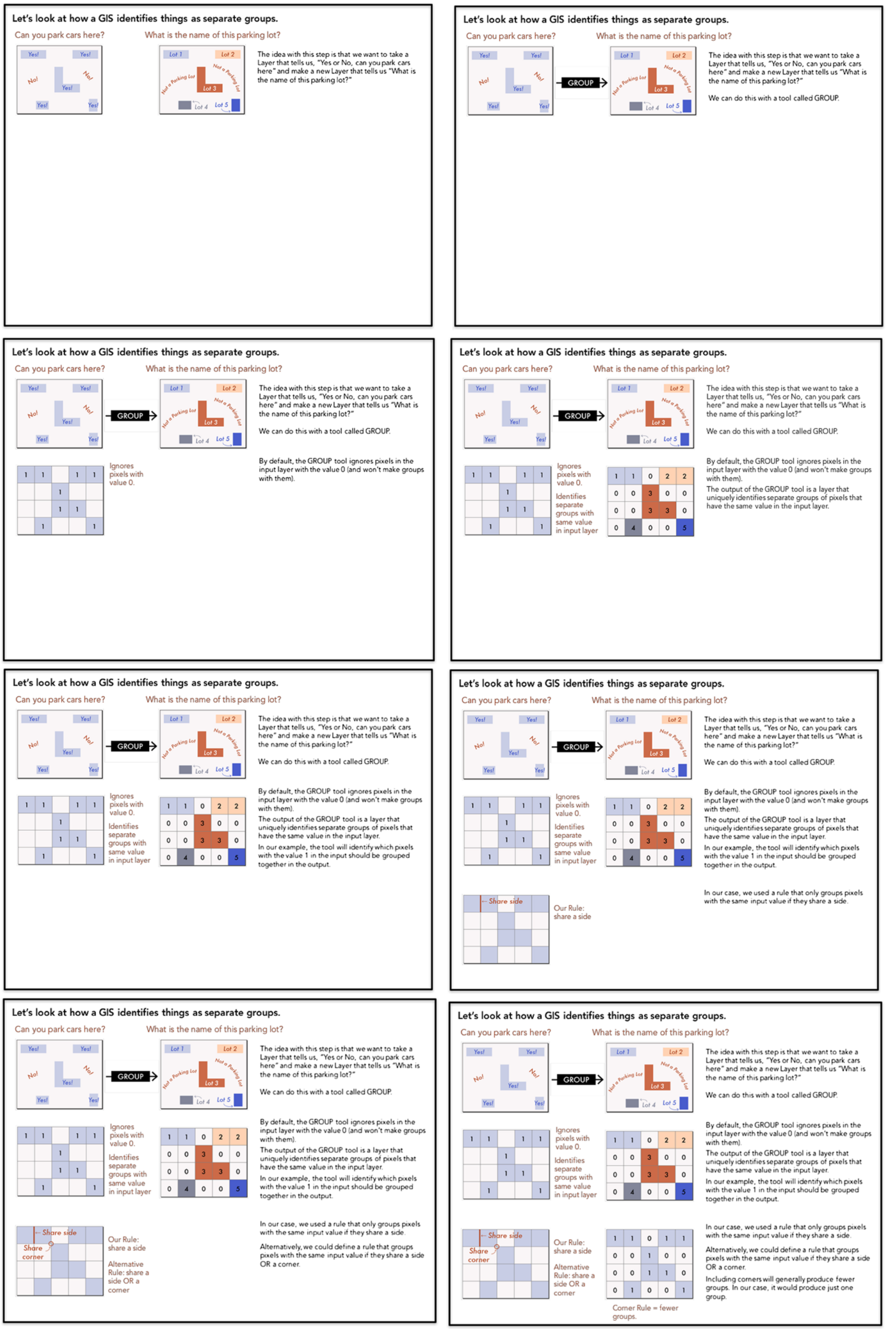

Fig. 1 Progression of eight frames in the segmented lesson for the DISTANCE Tool (slide 5 of 12 in the lesson)

choose a male voice to be consistent with how this lesson would be implemented in the college course from which it was adapted. Adding redundant narration to printed text and graphics can be justified on the grounds that it gives learners options for how they receive the verbal information (i.e., in spoken form or printed form). However, based on the cognitive theory of multimedia learning and cognitive load theory, adding redundant spoken text to graphics with printed text is not expected to aid learning if students attend to both sources because the added spoken text is redundant with the printed text. Adding redundant narration can cause extraneous processing such as trying to reconcile the two verbal strings (Kalyuga and Sweller 2014; Mayer and Fiorella 2014). In this case, the redundant group would perform worse or no better than the non-redundant group on tests of learning outcome.

In contrast, if learners in the redundant group ignore the printed text they can use their visual channel for processing the graphics and their auditory channel for processing the words, thereby effectively expanding cognitive capacity; this approach is consistent with the modality principle—people learn better from spoken words and graphics than from printed words and graphics (Ginns 2005; Low and Sweller 2014; Mayer 2009; Mayer and Pilegard 2014). In this case, the redundant group would perform better than the non-redundant group on tests of learning outcome.

Alternatively, if learners in the redundant group ignore the narration and focus on the printed text and graphics they should perform just as well as the non-redundant group on learning outcome tests. Redundancy may be helpful when the printed text differs in form or length from the spoken text (Mayer and Johnson 2008; Yue et al. 2013). The present study allows for an extension of redundancy principle to a new format (i.e., slideshow) and new way of creating segments (i.e., as steps in a worked example for solving a geography problem).

The experimental comparison in this study (onscreen text and graphics vs. onscreen text, narration, and graphics) is different from the typical comparison between narration and graphics versus onscreen text, narration, and graphics (Kalyuga and Sweller 2014; Mayer and Pilegard 2014). Thus, in the present study, we are extending the redundancy principle to a less studied way of comparing non-redundant and redundant treatments. However, cognitive theory still makes the same prediction that verbal redundancy is not helpful (or possibly harmful) in multimedia lessons.

The major independent variables in this study are: *segmenting*–whether or not each slide of the lesson is broken into parts that appear on the screen in response to the learner pressing a key; and *redundancy*—whether or not simultaneous narration is added to onscreen text and graphics. The major dependent measure is *transfer test performance*—score on a 6-item open-ended transfer test with a total possible score ranging from 0 to 6 and score on each item ranging from 0 to 1. Secondary dependent measures are self-reported ratings on a Likert scale from 1 to 5 for five individual items (i.e., level of enjoyment, desire for similar lessons, how appealing the lesson was, level of difficulty, and level of effort). A covariate is *exposure time*—the amount time from when the learner clicks to start the lesson to when the learner clicks to exit from the final slide of the lesson.

Research questions

The primary research question in the study is:

1. Does segmenting improve transfer test performance? Based on cognitive theory, we predict that the new form of segmenting used in the present study will result in better

transfer test performance than a non-segmented presentation. We focus on near transfer test items–which require being able to use the material presented in the lesson to answer new questions—because our goal is to identify instructional methods that promote deep learning.

The secondary research questions are:

2. Does segmenting improve transfer test performance both when redundant narration is added and when it is not? Based on cognitive theory, we also predict that the new form of segmenting used in the present study will result in better transfer test performance than the non-segmenting group both when there is no added voice and when there is added voice.
3. Does redundancy improve transfer test performance? Based on cognitive theory, we predict, that adding redundant narration to a multimedia lesson with illustrations and text will not result in better transfer test performance than not receiving redundant narration.
4. Do the groups differ on self-report measures of affect? Based on cognitive theory, we expect students to express higher levels of satisfaction for the segmented/non-redundant lesson because it offers the highest level of learner control and responsiveness and the lowest level of extraneous content (Mayer 2014; Scheiter 2014).

Method

Participants and design

The participants were 196 non-geography college students recruited from a subject pool at a U.S. university. The mean age was 19.0 years ($SD = 1.2$); there were 49 men and 147 women; and the mean rating of prior knowledge of geography was 2.6 ($SD = 0.8$), which is considered in the low range. The experiment involved a 2 × 2 between subjects design with segmenting as the first factor, redundancy as the second factor, and exposure time as a covariate. In a 2 (segmented versus non-segmented) × 2 (redundant versus non-redundant) between-subjects design, there were 52 participants in the non-segmented/non-redundant group, 46 in the non-segmented/redundant group, 47 in the segmented/non-redundant group, and 51 in the segmented/redundant group.

Materials and apparatus

The paper-based materials consisted of an informed consent form, participant questionnaire, six test sheets, and a post-questionnaire.

The consent form described the study and participant safeguards and was printed on an 8.5 × 11 in sheet of paper. The participant questionnaire solicited basic information including the student's sex, age, major, and self-rating of experience in geography on a 5-point scale from 1 (low) to 5 (high), i.e. "Please rate your knowledge of geography." The participant questionnaire was printed on an 8.5 × 11 in sheet of paper.

The six test sheets each presented a transfer problem to solve, such as:

"Please explain how the GROUP tool works."
"Please explain how the DISTANCE tool works."

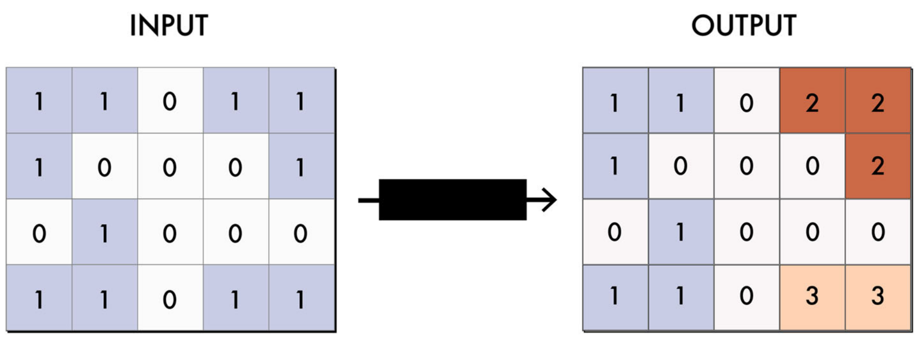

Fig. 2 Example of a test item. What is the name of the Tool and the Rule that could take this Input and make this output?

"Please explain how the EXTRACT MINIMUM tool works."
"What is the name of the tool that would take this input and produce this output?" (along with a 5 × 5 input matrix and a 5 × 5 output matrix similar to the ones used in the lesson). An example of this question sheet is shown in Fig. 2.
"What is the name of the tool that would take this input and produce this output?" (along with a different 5 × 5 input matrix and a 5 × 5 output matrix similar to the ones used in the lesson).
"Please fill in the values for RECLASS TABLE below that could take this input and produce this output." (along with an input table and output table with a RECLASS arrow between them and a blank RECLASS table with columns for F, T, and N).

At the bottom of each 8 .5 × 11 in sheet was the statement: "PLEASE KEEP WORKING UNTIL YOU ARE TOLD TO STOP." The test items were created by the course instructor and were similar to those used in previous offerings of the course that included GIS. The test items are intended to measure near transfer, that is, being able to use the presented material to answer new questions that require the learned knowledge. We avoided experimenter bias by using exactly the same procedure for administering the test for all participants, by scoring the answers using an objective rubric with scorers who were unaware of each participant's treatment group, and by establishing inter-rater reliability for scoring. The items represent a form of near transfer, that is, using the presented material to solve problems and answer questions like those in the lesson.

The post-questionnaire, printed on an 8.5 × 11 in sheet, asked students to give ratings on a 5-point scale for five items from low (1) to high (5):

"I enjoyed learning from this lesson."
"I would like to learn from more lessons like this."
"Please rate how appealing this lesson was for you."
"Please rate how difficult this lesson was for you."
"Please rate how much effort you exerted on this lesson."

This is a preliminary questionnaire in which each item is intended to evaluate one factor.

The computer-based materials consisted of four versions of a 12-slide lesson on how to use a geographic information system (GIS) to solve an example problem. The example problem began with a campus map of a dorm and surrounding parking lots and sought to determine which parking lots are within ½ mile of the dorm and which ones are not. The slides (1) present a map and problem statement, (2) show the steps using IDRISI (© Clark Labs) GIS operations, (3) show how a GIS stores map layers as spatial information in a grid, (4) introduce the GROUP tool, (5) show how to use the GROUP tool on the parking lot problem, (6) introduce the DISTANCE tool, (7) show how to use the DISTANCE tool on the parking lot problem, (8) introduce the EXTRACT tool, (9) show how to use the EXTRACT tool on the parking lot problem, (10) introduce the RECLASS tool, (11) show how to apply the RECLASS tool to the parking lot problem, and (12) review the entire procedure using each of the tools. The non-segmented/non-redundant version (base) contains graphics on the left side and printed words on the right side of each slide and each press of the arrow key brings on the next slide. For example, the last frame in Fig. 1 shows a slide explaining how the DISTANCE tool can be applied to the parking lot problem (i.e., slide 5 out of 12 slides).

The segmented/non-redundant version is identical except that each press of the arrow key adds another portion to the slide (consisting of a new illustration on the left, new text on the right, or both). The eight frames in Fig. 1 show the progression of what the learner sees added to a slide after pressing the arrow key in the part of the lesson explaining how the DISTANCE tool applies to the parking lot problem (i.e., slide 5 out of 12 slides). The segments were created by breaking the procedure for a given GIS tool into meaningful steps–with one step or major sub-step per segment. We focused on steps because these are the main conceptual components in each GIS tool.

The non-segmented/redundant version is identical to the base version except that there also is a recorded human male voice reading the text for each slide, and the segmented/redundant version is identical to the base version except the presentation is segmented and each segment also includes a human male voice reading the text. The material was originally developed and used in a college geography course that used a blended learning approach; however, the present lab-based experiment examines only one online GIS lesson in order to determine how best to design online slideshow lessons that could be used for home study in a college course.

The apparatus consisted of three iMac computer systems with 20-in color screens and over-the-ear headphones. Digital stopwatches were used to record exposure time.

Procedure

There were up to three participants in each session, with all participants in each session randomly assigned to the same group. Each participant was seated in a cubicle facing a computer, without visual access to the other participants. First, participants read and signed the informed consent form, and then completed the participant questionnaire at their own pace. Informed consent was obtained from all participants in the study. Then, after a brief introduction, the experimenter started the lesson on each computer. Participants were instructed to press the right arrow key to move forward and to press the back arrow key to move backward. Participants were asked to study the material carefully at their own pace and be prepared to answer questions based on the lesson. The experimenter monitored and recorded each participant's exposure time by using a digital stopwatch; the timer was started when the student clicked to start the lesson and stopped when the student clicked to exit the final slide. After the participant completed the lesson, the experimenter administered the 6-item test by giving the participant one test sheet at a time for 2.5 min. After 2.5 min, the experimenter collected the test sheet and handed out the next one. After the sixth test sheet was completed, the experimenter handed out the post-experimental questionnaire to be completed at the participant's own pace. Consistent with techniques used in prior research (Mayer 2009), we maintained a time limit on each question to insure that participants had sufficient time to think about each question and did not skip over any questions. The entire session lasted up to 30 min. We followed standards for ethical treatment of human subjects and obtained Institutional Review Board (IRB) approval.

Scoring

The transfer test questions were scored using a rubric developed by a GIS course instructor. Students received 0–1 point for each question, with partial points given for each part in multi-part questions. The transfer test score could range from 0 to 6. The tests were scored independently by two scorers who were not aware of the treatment group of the participants. The inter-rater reliability based on a Pearson correlation of test scores was $r = 0.97$ ($p < .001$), which indicates a very strong agreement between raters. In cases where the raters did not agree, an average score of the raters' scores was used.

Results and discussion

Do the groups differ on basic characteristics?

A preliminary issue is whether the groups differed on basic characteristics that might be relevant to test performance. The groups did not differ significantly (at $p < .05$) on age or mean rating of prior knowledge (based ANOVAs), or on proportion of men and women (based on Chi square tests). We conclude that there is no evidence that the groups differed on basic characteristics at the onset of the study.

Do the groups differ in exposure time?

The mean exposure time in seconds was 434.6 ($SD = 102.8$) for the non-segmented/non-redundant group, 625.4 ($SD = 105.0$) for the non-segmented/redundant group, 532.4 ($SD = 170.1$) for the segmented/non-redundant group, and 632.4 ($SD = 117.4$) for the segmented/redundant group. A 2×2 ANOVA with segmenting and redundancy as between-subjects factors revealed a significant effect for segmenting in which students who received the segmented version ($M = 584.4$, $SD = 152.8$) took significantly more time with the lesson than those who received the non-segmented version ($M = 524.2$, $SD = 140.8$), $F(1, 192) = 8.43, p = .004, d = 0.29$. There also was a significant effect for redundancy in which students who received the redundant version ($M = 629.1$, $SD = 111.2$) took significantly more time with the lesson than those who received the non-redundant version ($M = 481.0$, $SD = 146.6$), $F(1, 192) = 64.93$, $p = .000$, $d = 1.14$. Finally, there was a significant segmenting x redundancy interaction in which the non-segmented/non-redundant version took the least amount of time and the segmented/redundant version took the most time, $F(1, 192) = 6.31$, $p = .013$.

Overall, more time was required in lessons that contained features that slowed down the pace of presentation—segmenting, which required more button clicks per slide, and redundancy, which required listening to spoken text (which normally takes longer than reading the same text). Time on task is generally considered an important factor affecting student learning (Hattie 2009; van Gog 2013), but the increased time on task for the two treatments can be attributed to different causes. The additional time for the redundancy group is attributable to the artifact that it takes considerably longer to listen to spoken words than to read the same printed words, whereas the additional time for the segmenting group is not attributable to a design artifact (because the time required for added button presses is negligible so exposure time differences may be attributable to students choosing to spend more time.)

Does segmenting improve transfer test performance?

Table 1 shows the mean transfer test score and standard deviation for each group. To answer research questions 1, 2, and 3, an ANOVA was applied to the transfer test data with transfer test score as the dependent measure, and segmenting and redundancy as between subjects variables. The main prediction (from research question 1) is that learning is enhanced when each full slide in a slideshow is broken down into bite-sized segments that are presented under learner control. Consistent with the segmenting principle, students who received a segmented lesson ($M = 1.72$, $SD = 1.02$) scored significantly higher on the transfer test than students who received a non-segmented lesson ($M = 1.40$, $SD = 0.86$), $F(192) = 5.45$, $p = .021$, $d = 0.34$.

In line with research question 2, the same pattern favoring segmented over non-segmented lessons was found when there was no added narration and when there was added narration, which is reflected in the finding that there was no significant interaction between segmenting and redundancy, $F(192) = 0.00$, $p = 0.94$. When we look only at non-redundant presentations (i.e., no narration added), we find a segmenting effect with an effect size of $d = .34$, and when we look at redundant presentations (i.e., narration added that corresponds to the printed text), we find a segmenting effect with an effect size of $d = .33$. Importantly, the segmenting effect remains significant even when exposure time is included as a covariate in an ANCOVA, $F(191) = 4.10$, $p = .044$, $d = .31$. This segmenting effect for transfer test performance is the major empirical finding in this study.

Does redundancy improve transfer test performance?

In line with research question 3, there was no significant effect for redundancy, $F(1, 192) = 0.33$, $p = .561$, and no significant interaction involving redundancy, $F(1, 192) = 0.00$, $p = .945$. An ANCOVA with exposure time as a covariate also yielded no significant effects or interactions involving redundancy. These results are most consistent with the idea that learners did not rely heavily on the spoken text during learning.

Table 1 Mean score (and standard deviation) on the transfer test for four groups

Group	M	SD
Non-segmented/non-redundant	1.36	0.81
Non-segmented/redundant	1.43	0.93
Segmented/non-redundant	1.67	1.00
Segmented/redundant	1.76	1.04

Table 2 Mean score (and standard deviation) on the self-report items for four groups

Group	Enjoyed		Like more		Appealing		Difficult		Effort	
	M	SD	M	SD	M	SD	M	SD	M	SD
Non-segmented/non-redundant	1.38	1.12	1.21	1.13	1.33	1.10	4.19	0.71	2.87	1.08
Non-segmented/redundant	1.72	1.17	1.59	1.11	1.76	1.08	3.74	0.88	3.17	0.88
Segmented/non-redundant	1.85	0.94	1.74	1.16	1.80	1.11	3.63	0.83	3.00	0.82
Segmented/redundant	1.55	1.15	1.31	1.16	1.37	1.11	3.86	0.92	2.88	0.93

1 = low and 5 = high

Do the groups differ on self-report measures?

Although our major focus is on learning outcomes, we also included some preliminary measures of affect and motivation in order to provide more context, as reflected in research question 4. Table 2 shows the mean rating and standard deviation for each group on each of the five self-report questionnaire items, with 1 = low and 5 = high. A multivariate ANOVA conducted on the questionnaire items with segmenting and redundancy as between subjects factors revealed no significant main effects for segmenting or redundancy. However, there was a significant interaction at $p < .05$ for each of the first four items in which the worst rating was for the non-segmented/non-redundant group and best rating was for the segmented/non-redundant group [enjoy: $F(1, 191) = 3.97$, $p = .047$; like more: $F(1, 191) = 6.01$, $p = .015$; appealing: $F(1, 191) = 7.53$, $p = .007$; difficult: $F(1, 191) = 8.16$, $p = .005$; effort: $F(1, 191) = 2.51$, $p = .12$]. In terms of affective and motivational measures, the best treatment consistently is segmented without added narration.

General conclusion

Empirical contributions

Overall, students learned better from a slideshow lesson when learners saw the content on each slide as a progression of smaller segments controlled by pressing an arrow key rather than by seeing full slides all at once. This segmenting effect for learning outcome was present both when redundant voice was added and when it was not. In terms of self-report measures of affect and motivation, the segmented lesson without redundant narration was consistently rated best. This study shows that the segmenting principle applies to learner-paced online slideshow presentations and to geography content. In contrast, adding voice to graphics with printed text does not significantly improve learning. These results show that earlier research on the segmenting effect for narrated animations and video also applies to the instructional format of learner-paced slideshows.

This work is in line with Shavelson and Towne's (2002) admonition that scientific research in education requires that we "replicate and generalize across studies" (i.e., principle 5 out of 6). The need for careful replications that extend previous work is indicated by the increasing emphasis on meta-analyses in our field which rely on multiple studies on the same effect (Hattie 2009) as well as the so-called "crisis of replication" in which some key effects in cognitive psychology could not be replicated (Pashler and Wagenmakers 2012, p. 528; Stroebe and Strack 2014, p. 59). The present study replicates the segmenting principle in a new computer-based learning context (i.e., a slideshow rather than a narrated animation), using complex material from an actual college class rather a short animation intended for lab studies, using new segmenting procedures (i.e., adding a new step to the screen for each press of the arrow key rather than showing all the material at once), and using new tests of learning (i.e., making judgments about various GIS commands). It should be noted that our implementation of segmenting is not the same as bullet-by-bullet animation of PowerPoint slides, especially in light of the fact our implementation of segmenting includes learner control (rather than instructor control in a face-to-face slideshow presentation) and is based on coherent chunks of content (rather than isolated factoids in a list). Given the massive use of slideshows as a common educational technology, as well as the increasing use of slideshows in online instruction, this work tests a new way to apply the segmenting principle in this important venue.

Theoretical contributions

On the theoretical side, the results support the idea that segmenting can reduce cognitive load by managing essential processing—that is, cognitive processing needed to mentally represent the material. Students understand better when complex material is presented in bite-size chunks, each of which can be digested before moving on to the next portion. When a full screen full of complicated material is presented at once, the learner can be overwhelmed and is more likely to miss key information. This work contributes to instructional theory by extending the conceptualization of segment size to now include meaningful steps in a procedure shown on a portion of a slide screen.

Practical contributions

On the practical side, the results show that adding a simple feature—segmenting—can increase student learning even when the content of the lesson is identical. Even the modest form of segmenting we used increased test performance by a third of a standard deviation (both when redundant narration was present and when it was not). This supports the *segmenting principle*—people learn better when a complex lesson is broken into user-paced segments. A new aspect of the segmenting principle is that it now has been shown to apply to self-paced slideshow presentations, which can be used for home study in a blended learning course environment.

Limitations and future directions

The study is limited by being a short-term lab-based study. Further work is needed to determine whether segmenting effects hold in longer, course-based contexts and with other subject content. It also is worthwhile to examine whether segmenting effects hold for learners with higher prior knowledge and higher interest in the material. We also acknowledge that the time a student spends on slides is not necessarily a pure indication that the student was reading during all that time, so a more direct measure of time spent studying the material would be useful. The post-questionnaire contained only one question to tap each factor, but including more items for each factor would allow researchers to examine the psychometric properties of the questionnaire. Finally, it would be worthwhile to further investigate the ideal size for a segment.

Funding This project was supported by Grant 1504940 from the National Science Foundation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Atkinson, C. (2008). *Beyond bullet points*. Redmond, WA: Microsoft Press.

Ayres, P. (2006). Impact of reducing intrinsic cognitive load on learning in a mathematical domain. *Applied Cognitive Psychology, 20,* 287–298.

Boucheix, J., & Guignard, H. (2005). What animated illustrations conditions can improve technical document comprehension in young students? Format, signaling and control of the presentation. *European Journal of Psychology of Education, 20,* 369–388.

Boucheix, J., & Schneider, E. (2009). Static and animated presentations in learning dynamic mechanical systems. *Learning and Instruction, 19*(2), 112–127.

Brunken, R., Plass, J., & Leutner, D. (2003). Direct measurement of cognitive load in multimedia learning. *Educational Psychologist, 38,* 53–61.

Clark, R. C., & Mayer, R. E. (2016). *e-Learning and the science of instruction* (4th ed.). New York: Wiley.

Duarte, N. (2008). *Slideology: The art and science of creating great presentations*. Sebastopol, CA: O'Reilly.

Ginns, P. (2005). Meta-analysis of the modality effect. *Learning and Instruction, 15,* 313–332.

Hasler, B. S., Kersten, B., & Sweller, J. (2007). Learner control, cognitive load, and instructional animation. *Applied Cognitive Psychology, 21,* 713–729.

Hassanabadi, H., Robatjazi, E. S., & Savoji, A. P. (2011). Cognitive consequences of segmentation and modality methods in learning from instructional animations. *Procedia—Social and Behavioral Sciences, 30,* 1481–1487.

Hattie, J. (2009). *Visible learning*. New York: Routledge.

Kalyuga, S., & Sweller, J. (2014). The redundancy principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 247–262). New York: Cambridge University Press.

Kosslyn, S. M. (2007). *Clear and to the point: 8 psychological principles for compelling PowerPoint presentations*. New York: Oxford University Press.

Lee, H., Plass, J. L., & Homer, B. D. (2006). Optimizing cognitive load for learning from computer-based science lessons. *Journal of Educational Psychology, 98,* 902–913.

Low, R., & Sweller, R. (2014). The modality principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 227–246). New York: Cambridge University Press.

Lusk, D. L., Evans, A. D., Jeffrey, T. R., Palmer, K. R., Wikstrom, C. S., & Doolittle, P. E. (2009). Multimedia learning and individual differences: Mediating the effects of working memory capacity with segmentation. *British Journal of Educational Technology, 40*(4), 636–651.

Mautone, P. D., & Mayer, R. E. (2007). Cognitive aids for guiding graph comprehension. *Journal of Educational Psychology, 99,* 640–652.

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

Mayer, R. E. (2011). *Applying the science of learning*. Boston, MA: Pearson.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 43–71). New York: Cambridge University Press.

Mayer, R. E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology, 93,* 390–397.

Mayer, R. E., Dow, G., & 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., & Fiorella, L. (2014). Principles for reducing extraneous processing in multimedia learning: Coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles. In R.

E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 279–315). New York: Cambridge University Press.
Mayer, R. E., & Johnson, C. I. (2008). Revising the redundancy principle in multimedia learning. *Journal of Educational Psychology, 100,* 380–386.
Mayer, R. E., & Pilegard, C. (2014). Principles for managing essential processing in multimedia learning: Segmenting, pre-training, and modality principles. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 316–334). New York: Cambridge University Press.
Moreno, R. (2007). Optimising learning from animations by minimising cognitive load: Cognitive and affective consequences of signaling and segmentation methods. *Applied Cognitive Psychology, 21,* 765–781.
Pashler, H., & Wagenmakers, E.-J. (2012). Editor's introduction to the special issue on replicability in psychological science: A crisis in confidence? *Perspectives in Psychological Science, 7,* 528–530.
Plass, J. L., Moreno, R., & Brunken, R. (2010). *Cognitive load theory*. New York: Cambridge University Press.
Reynolds, G. (2008). *Presentation zen: Simple ideas on presentation design and delivery*. Berkeley, CA: New Riders.
Scheiter, K. (2014). The learner control principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 487–512). New York: Cambridge University Press.
Shavelson, R. J., & Towne, L. (2002). *Scientific research in education*. Washington, DC: National Academy Press.
Spanjers, I. A. E., Wouters, P., van Gog, T., & van Merrienboer, J. J. G. (2011). An expertise reversal effect of segmentation in learning from animated worked-out examples. *Computers in Human Behavior, 27,* 46–52.
Stiller, K. D., Freitag, A., Zinnbauer, P., & Freitag, C. (2009). How pacing of multimedia instructions can influence modality effects : A case of superiority of visual texts. *Australasian Journal of Educational Technology, 25*(2), 184–203.
Stroebe, W., & Strack, F. (2014). The alleged crisis and the illusion of exact replication. *Perspectives on Psychological Science, 9*(1), 59–71.
Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. New York: Springer.
van Gog, T. (2013). Time on task. In J. Hattie & E. M. Anderman (Eds.), *International guide to student achievement* (pp. 432–433). New York: Routledge.
Yue, C. L., Bjork, E. L., & Bjork, R. A. (2013). Reducing verbal redundancy in multimedia learning: An undesired desirable difficulty? *Journal of Educational Psychology, 105,* 266–277.

Richard E. Mayer is a Distinguished Professor in the Department of Psychological and Brain Sciences at the University of California, Santa Barbara.

Jeffrey T. Howarth is an Associate Professor in the Department of Geography at Middlebury College.

Michelle Kaplan is an undergraduate Psychology major at the University of California, Santa Barbara.

Sara Hanna is an undergraduate Psychology major at the University of California, Santa Barbara.