Instructional Science (2018) 46:947–971
https://doi.org/10.1007/s11251-018-9458-0

ORIGINAL RESEARCH

Laptop versus longhand note taking: effects on lecture notes and achievement

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Received: 7 April 2017 / Accepted: 7 June 2018 / Published online: 15 June 2018

Abstract
There has been a shift in college classrooms from students recording lecture notes using a longhand pencil-paper medium to using laptops. The present study investigated whether note-taking medium (laptop, longhand) influenced note taking and achievement when notes were recorded but not reviewed (note taking's process function) and when notes were recorded and reviewed (note taking's product function). One unique aspect of the study was determining how laptop and longhand note taking influence the recording of lecture images in notes and image-related achievement. Note-taking results showed that laptop note takers recorded more notes (idea units and words) and more verbatim lecture strings than did longhand note takers who, in turn, recorded more visual notes (signals and images) than did laptop note takers. Achievement results showed that when taking laptop notes, the process function of note taking was more beneficial than the product function of note taking (i.e., better image-related learning and similar text-related learning). When taking longhand notes, the product function of note taking was more beneficial than the process function of note taking (i.e., better text-related learning and similar image-related learning). Achievement findings suggest that the optimal note-taking medium depends on the nature of the lecture and whether notes are reviewed.

Keywords Note taking · Lecture learning · Laptop

Nearly all college students record lecture notes (Bonner and Holliday 2006; Castelló and Monereo 2005; Kiewra 2002), and they are wise to do so because note taking is positively related to achievement (e.g., Kiewra 1985; Nye et al. 1984; Peverly et al. 2014). Note taking boosts achievement because it potentially serves both a process (the taking of notes is helpful) and product (the review of notes is helpful) function. Traditionally, students have

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taken notes using a pencil-paper longhand medium. Advancements in technology, however, have increased the number of students who take lecture notes using a laptop computer (Fried 2008; Lauricella and Kay 2010) to the point where nearly one-third of college students record class notes on laptops (Aguilar-Roca et al. 2012). Given this increase, the purpose of the present study was to determine how the process and product functions of laptop and longhand note taking differentially impact students' notes and achievement. To make these determinations, various note-taking indices and achievement outcomes were examined. Because lectures often contain visual images that might be especially difficult for laptop note takers to note (Mosleh et al. 2016; Reimer et al. 2009), the present study also measured the presence of images in notes and image-related achievement.

Note-Taking Function

Theoretically, note taking serves two functions: process and product (Di Vesta and Gray 1972; Kiewra 1985). The process function suggests that the activity of recording lecture notes is more effective than listening-only. This note-taking advantage is explained by two hypotheses. One is the translation hypothesis (Conway and Gathercole 1990; De Haan et al. 2000), which posits that hearing and writing lesson material is better than simply hearing it because additional writing leads to more distinctive encoding and better memory for the lesson material. The other is the generative hypothesis (Wittrock 1974), which posits that note takers better assimilate lecture ideas with prior knowledge than do listeners (Peper and Mayer 1978, 1986; Shrager and Mayer 1989) because the note-taking process encourages students to paraphrase, organize, and integrate new lesson material in line with related prior knowledge.

Research on the process function is, however, mixed (Kiewra 1985; Kobayashi 2005), with some studies favoring note taking over listening (Bligh 2000; Einstein et al. 1985; Kiewra et al. 1991; Suritsky and Hughes 1991) and others showing no benefit of note taking over listening (Fisher and Harris 1973; Glover et al. 1980; Riley and Dyer 1979). Kiewra and Fletcher (1984), in fact, found no evidence for note takers linking lecture ideas to prior knowledge even when asked to do so. Kiewra et al. (1991) argued against the generative benefits of the note taking, saying that the note-taking process is cognitively demanding, potentially overloads memory (Sweller 1994), and interferes with immediate learning:

> During lecture learning, students must continuously and simultaneously listen, select important ideas, hold and manipulate lecture ideas, interpret the information, decide what to transcribe, and record notes. Some resources are additionally spent on the mechanical aspects of note taking such as spelling, grammar, and notational style. It is unlikely that many resources are available for more generative processing of lecture information. (Kiewra et al. 1991, p. 241)

Other researchers have also found the activity of note taking cognitively demanding and sometimes ineffective when recorded notes are not reviewed (Bui and Myerson 2014; Katayama and Robinson 2000; Piolat et al. 2005).

The product function suggests that reviewing an externally stored set of notes aids learning because review permits students to commit noted ideas to memory through rehearsal, organization, or elaboration when more time permits following the lecture (Kiewra 1985;

Kiewra et al. 1991). Research confirms that reviewing lecture notes boosts achievement substantially compared to no review (e.g., Armbruster 2000; Fisher and Harris 1973; Kiewra 1985; Knight and McKelvie 1986). When the process and product functions of note taking are compared, the product function is usually more effective (Kiewra et al. 1991; Kobayashi 2005; Rickards and Friedman 1978). This comparison suggests that the true value of note taking is more in the review of notes than in their recording.[1]

Note-Taking Medium

Three recent studies containing multiple experiments investigated the achievement and note-taking advantages of laptop versus longhand note taking. In the first study (Bui et al. 2013, Experiment 1), college students listened to a brief lecture and either recorded notes using laptop or longhand methods. With regard to note taking, laptop notes contained more lecture ideas and more verbatim strings than did longhand notes. Regarding achievement, laptop note takers recalled more facts (main ideas and important details) than longhand note takers on an immediate test without review (process function).

In the second study (Mueller and Oppenheimer 2014), students watched a series of brief lectures and either recorded notes using laptop or longhand methods. Regarding immediate testing (Experiment 1), longhand note takers achieved more on concept, but not fact, items than laptop note takers when notes were recorded but not reviewed (process function). The product function was not investigated in Experiment 1. Regarding delayed testing (Experiment 3), there was a note-taking function by medium interaction. Laptop and longhand note takers performed comparably on fact and concept items when notes were recorded but not reviewed (process function), whereas longhand note takers achieved more than laptop note takers on those same items when notes were both recorded and reviewed (product function). Regarding note taking, laptop notes contained more words and more verbatim lecture strings than did longhand notes across all three experiments, even when laptop note takers were warned against recording verbatim notes in Experiment 2.

In the third study (Fiorella and Mayer 2017, Study 2), students studied verbal information about the human respiratory system presented on ten 3-inch by 5-inch flashcards and recorded notes using longhand or laptop methods. Students were instructed to study one card at a time and to not return to a previously studied card. After studying, all participants had 3 min to review their notes before taking an achievement test that contained retention, transfer, and drawing items. Laptop note takers outperformed longhand note takers on all three item types. This laptop achievement advantage occurred even though longhand note takers used more spatial strategies, such as mapping and drawing, than laptop note takers. The laptop group, however, recorded more words than the longhand group.

Looking across the three studies investigating note-taking medium, common findings pertain to note taking. First, laptop note takers recorded more information in the form of idea units (Bui et al. 2013) or words (Fiorella and Mayer 2017; Mueller and Oppenheimer 2014) than longhand note takers. These findings are not surprising because adults type at

[1] Kiewra et al. (1991) argued that the product function of note taking is best represented by those who only review notes (such as those provided by the instructor or borrowed from a fellow student) but do not also record notes. They argued that both recording and reviewing notes is representative of the combined process and product functions of note taking rather than the product function alone.

a rate of 33 wpm (Karat et al. 1999) but write at a rate of only 22 wpm (Brown 1998), and transcription speed is positively related to the quantity of recorded lecture notes (Peverly et al. 2007). These findings are important because both note-completeness indices (idea units and words) are positively related to achievement (Peverly et al. 2003; Williams and Worth 2002).

Second, longhand note takers recorded more generative notes than laptop note takers. Two studies (Bui et al. 2013; Mueller and Oppenheimer 2014) reported that laptop notes contained more verbatim lecture strings than did longhand notes. Laptop note takers approached note taking as a non-generative transcription process by writing lecture ideas word for word, whereas longhand note takers approached note taking as a generative process by writing lecture ideas in one's own words. Although Fiorella and Mayer (2017) did not examine verbatim notes, they found that laptop notes were written in words only, whereas longhand notes contained self-generated illustrations such as maps and drawings.

Taken together, it appears that different note-taking mediums stimulate different note-taking strategies. Laptop note takers used primarily verbal note-taking strategies and approached note taking as a transcription process. Longhand note takers used both verbal and spatial note-taking strategies and approached note taking as a generative process, wherein lesson ideas were noted in one's own words and complemented with illustrations.

The studies investigating note-taking medium were at odds, though, with respect to achievement. Regarding the process function of note taking (when notes were not reviewed), laptop note takers achieved more than longhand note takers in one study (Bui et al. 2013, Experiment 1), whereas longhand note takers achieved more than laptop note takers in another study (Mueller and Oppenheimer 2014). Regarding the product function of note taking (when notes were reviewed), laptop note takers achieved more than longhand note takers in one study (Fiorella and Mayer 2017, Study 2), whereas longhand note takers achieved more than laptop note takers in another study (Mueller and Oppenheimer 2014, Experiment 3). Bui et al. (2013) credit laptop achievement advantages to note-taking quantity: laptop note takers recorded more complete notes than longhand note takers. They contend that the process function of note taking is enhanced by recording more notes, and previous studies support this contention (Bligh 2000; Einstein et al. 1985; Kiewra et al. 1991; Suritsky and Hughes 1991). Bui et al. (2013), however, also found that the benefits of taking verbatim notes might be lost if the notes are not reviewed. Mueller and Oppenheimer (2014), meanwhile, credit longhand achievement benefits to the better quality of those notes compared to laptop notes. They contend that longhand note takers, relative to laptop note takers, were more engaged and thoughtful during the note-taking process and that their resulting more paraphrased (versus verbatim) notes were a more meaningful product for review. Fiorella and Mayer (2017) found that although longhand note takers used spatial note-taking strategies, they achieved less than laptop note takers on the drawing test. They suggested that longhand note takers experienced greater extraneous cognitive processing during learning compared to laptop note takers because spatial strategies required more time and cognitive effort than verbal strategies.

Visual Images in Notes

Investigating the presence or absence of visual images (e.g., graphs, tables, figures, etc.) in notes is important because adding visual images to verbal lesson materials helps illustrate lesson material and increase student learning (ChanLin 1998). Mayer (2009) summarized this benefit in his multimedia principle: students learn better from words and visual images than from words alone (Mayer and Gallini 1990). The advantageous addition of images also fits with the dual-coding theory (Clark and Paivio 1991) that learning is best when material is processed both verbally and visually. However, visual images might be harder to capture using a laptop because of technological constraints (such as difficulty drawing an image or producing a graph). In fact, students reported that it was harder and slower to draw pictures, symbols, charts, and graphs when they used a laptop, versus longhand methods, for note taking (Reimer et al. 2009).

Among the three studies that investigated laptop and longhand note taking (Bui et al. 2013; Fiorella and Mayer 2017; Mueller and Oppenheimer 2014), only Fiorella and Mayer's study investigated visual images in notes. The researchers were particularly interested in the types of note-taking strategies students might use when studying a scientific text about respiration that contained verbal information but no images. They proposed that different note-taking mediums might encourage different note-taking strategies and learning outcomes. Specifically, they predicted that laptop note takers would use a verbal note-taking strategy (i.e., record notes in words only), whereas longhand note takers would use both verbal and spatial note-taking strategies (i.e., create visual images representing the respiratory system). Results confirmed that laptop note takers recorded information mainly in words and that longhand note takers recorded more images in notes than did laptop note takers. However, recording more images did not boost achievement. Surprisingly, laptop note takers outperformed longhand note takers on retention, transfer, and drawing tests.

Research Gaps and Limitations

The reviewed studies on laptop versus longhand note taking (Bui et al. 2013; Fiorella and Mayer 2017; Mueller and Oppenheimer 2014) have gaps or limitations addressed in the present study. First, those three studies contained a total of eight experiments, and only one of those (Mueller and Oppenheimer 2014, Experiment 3) investigated systematically the main and interactive effects of note-taking function (process, product) and note-taking medium (laptop, longhand). The present study did as well. Second, these studies used non-course related material or material presented in an unconventional way. In one study (Mueller and Oppenheimer 2014), college students viewed five different TED Talks (Experiments 1 and 2) or listened to four lectures over four general but unrelated topics (Experiment 3). In another study (Bui et al. 2013), college students listened to a lecture taken from a book that compared a popular film to the Crimean War event it depicted. In the third study (Fiorella and Mayer 2017), students viewed materials about the human respiratory system on 10 flashcards, which is not a typical instructional medium in college classroom learning. The present study used a lecture pertaining to educational measurement, a relevant topic for the educational psychology students who participated. Furthermore, although Fiorella and Mayer (2017) investigated the presence or absence of images recorded in laptop versus longhand notes and found that longhand note takers made more drawings in notes than did laptop note takers, their lesson material was presented via text rather than lecture and contained no provided images. The present study involved note taking from lecture rather than from text and used lecture material that contained images.

The Present Study

The primary purpose of the present study, then, was to further investigate to what extent different note-taking mediums (laptop, longhand) and note-taking functions (process, product) affect (a) lecture note-taking behaviors and (b) achievement. In this regard, the present study replicates Mueller and Oppenheimer's (2014) Experiment 3 design by investigating the interactive effects of note-taking function and note-taking medium. It does so, though, using authentic material, an achievement test that assesses both text-related and image-related learning outcomes, and a wider array of note-taking measures (verbatim notes, note quantity, and visual notes). A unique purpose of the present study was to examine how laptop and longhand methods influence note taking and achievement when the lecture contains visual images. To meet these purposes, college students recorded laptop or longhand notes (note-taking medium) while viewing a course-related lecture that contained several images and then reviewed or did not review notes (note-taking function) before taking an achievement test measuring text-related and image-related learning outcomes.

Methods

Participants and design

Participants were 126 undergraduate education majors enrolled in an educational psychology course at a large Midwestern university who participated to receive research credit. Eighty percent were female, and most were Caucasians (94%). Seventy-one percent were juniors and seniors, and 88% held grade-point averages of 3.0 or higher. Prior to participation, equal numbers of volunteering students were first assigned randomly to either the process or the product note-taking function group and received email notification of their participation time and place. The process and product function groups participated at different times in the same classroom setting. Upon arrival at the classroom, all participants were further assigned randomly to either longhand or laptop note-taking groups. Because some students failed to show up for the experiment, group sizes were slightly unequal. This 2×2 design produced four groups: longhand process ($n = 30$), longhand product ($n = 32$), laptop process ($n = 30$), and laptop product ($n = 34$).

Materials

A 23-min narrated PowerPoint lecture covered the topic of educational measurement. It was a pre-programmed, self-advancing presentation with accompanying narration. The audio-recorded narration contained 2696 words presented at a rate of 117 wpm. There were 23 PowerPoint slides in total. Each slide was presented for about 30 s to 1 min, and each displayed content with a center heading along with one or two bullet points containing brief verbal information (10 or fewer words) below the heading (an example appears in Fig. 3 in Appendix). The first slide was an overview of the lecture's four main topics: (a) levels of measurement, (b) measures of central tendency, (c) measures of dispersion, and (d) shapes of distributions. The next five slides covered the first topic, levels of measurement. The first slide was an overview of the four levels of measurement:

nominal, ordinal, interval, and ratio. Each of the next four slides covered one of the measurement levels in turn. For each measurement level, information about definition, characteristics, examples, and limitations was presented. A similar structure was used to present the next two topics (i.e., the three measures of central tendency—mean, median, and mode; and the three measures of dispersion—range, variance, and standard deviation). The last nine slides covered the fourth topic—shapes of distributions. This section first introduced frequency tables and then the four distributions: normal, negatively skewed, positively skewed, and bimodal. These nine slides also contained images to help participants visualize and understand the lecture's verbal information. One image was a frequency table, and the other eight images were graphs of distributions. Figure 4 in the Appendix is an example of a lecture slide with verbal information and image.

Narrated PowerPoint lecture is a common instructional presentation mode used in college courses such as psychology (Cramer et al. 2006), business (Keefe 2003), biology (Moravec et al. 2010), nursing (Corbridge et al. 2010), and cinema (Young 2009). Narrated PowerPoint lectures can be presented in class or viewed by students on their own outside of class (Mayer 2008).

Longhand note takers received blank paper and pens for note taking. Laptop note takers received laptops loaded with and left open to a blank Word document for note taking. All Word functions (e.g., bold, highlight, text alignment, tables, and indentation) were operational.

A distracter task was used to clear working memory between information acquisition and testing. It included 10 vocabulary multiple-choice questions taken from sample Scholastic Aptitude Test items.

The multiple-choice test contained 37 items and contained a mixture of fact, relationship, concept, and skill items. Items were constructed following guidelines for constructing items measuring varying learning outcomes (Gagné 1977; Gronlund 1998; Kiewra 2009). The test's overall internal consistency, as measured by Cronbach's alpha, was .804.

Because one focus of the present study was assessing image-related learning, two achievement scores were created: image-related and text-related. The image-related scores were based on 11 image-related items. These items pertained specifically to graphically represented images (e.g., images of distributions) in the PowerPoint lecture. For example, "In which distribution is the mode always greater than the mean?" The text-related scores were based on the remaining 26 items that assessed participants' knowledge of lecture content not supported by lecture images. For example, "Which two measures of dispersion indicate the average distance of scores from the center of a distribution?" The internal consistency coefficient for image-related items was .60 and was .74 for text-related items.

An exit survey collected participants' demographic information, lecture topic knowledge, typical note-taking completeness, note-taking medium preference, and attitudes about their experimental note-taking medium. Demographic information included participants' gender (a. Male, b. Female), ethnicity (a. Black/African American, b. Hispanic/Latino, c. Asian/Pacific Islander, d. Caucasian/White, e. Other), class standing (a. Freshman, b. Sophomore, c. Junior, d. Senior), and approximate cumulative GPA (a. 3.5–4.0, b. 3.0–3.49, c. 2.5–2.99, d. 2.0–2.49, e., below 2.0). The prior knowledge question asked whether participants had taken any courses that covered the topic of measurement (a. Yes, b. No). The next two questions asked participants about their typical note-taking completeness [How many notes do you usually take in class? (a) I don't take notes, (b) I take a few notes, (c) I take a lot of notes], and their note-taking medium preference [What note-taking medium do you commonly use? (a) Longhand, (b) Laptop]. Finally, the exit survey asked participants their attitudes about the experimental note-taking medium they used (laptop or longhand) in terms of effectiveness, ease of use, enjoyment, and likelihood of future use using a 1–6 Likert-type scale (1 = To a small degree, 6 = To a large degree).

Procedure

Once participants arrived in the experiment classroom and were situated, the researcher read instructions aloud informing them of the procedure. All participants were informed of the three experimental phases: learning phase ("You'll be presented with material to learn about the topic of educational measurement. Record notes in a way that is most helpful to you as in any college class"), testing phase ("You'll take a test on educational measurement that tests facts, relationships, recognition of new examples, and skills"), and exit survey phase ("You'll answer a few questions about yourself and about the methods you used during the study"). Those in the product group were additionally informed that they would have 15 min to review their recorded notes before the testing phase. All participants then carried out group-specific tasks. Finally, participants were debriefed and dismissed.

Scoring

All multiple-choice test items were scored objectively by computer. Image-related achievement scores were calculated using the average correct percentage of the 11 image-related items. Text-related achievement scores were calculated using the average correct percentage of the 26 text-related (non-image) items.

All notes were scored for idea units, words, verbatim strings, signals, and images. The first author scored all notes for idea units, signals, and images, and a trained rater independently scored about one third of notes to check reliability for these measures. Words and verbatim strings were scored by computer.

Idea units were established by assigning one point for each noted idea unit based on a rubric that included all 213 lecture idea units. An idea unit was defined as a conceptual unit composed of an argument and its relations (Kintsch 1988). A sample idea unit in the present study was: range (argument) is the difference between highest and lowest scores (relation). If an idea unit was present, then one point was assigned. If an idea unit was absent, then no point was assigned. Previous research confirms that there is a positive correlation between number of idea units recorded and achievement (Kiewra and Fletcher 1984). Interrater reliability, measured by Cohen's kappa, was .869, indicating excellent agreement between two raters (Cohen 1988).

To assess recorded words and verbatim strings, all longhand notes were first transcribed to electronic format to match laptop format. The number of words was calculated using the "word count" function in Microsoft Word so that laptop and longhand notes were counted using the same rules and so that human errors in counting were prevented. Previous research shows that the number of words recorded is positively correlated with achievement (Boyle and Forchelli 2014; Mueller and Oppenheimer 2014). Verbatim strings, measured by the percentages of one-, two-, and three-word textual overlap between each participant's notes and the lecture transcript, were computed using an n-gram program (Mueller and Oppenheimer 2014). Previous research shows that the presence of verbatim strings in notes is negatively correlated with achievement because verbatim note taking is considered a transcription process reflective of shallow processing (Mueller and Oppenheimer 2014). Another study (Bui et al. 2013), however, suggests that verbatim note taking might be effective for laptop note taking when those notes are reviewed.

The number of visual signals in notes was also scored. Visual signals included markings that designated certain information as particularly important (e.g., bolding, underlining, all-capital letters, stars, arrows, boxes, and circles). The number of visual signals was counted and interrater reliability was good (Cohen's kappa was .817). Previous research shows that visual signals direct attention to key information and lead to higher recall than when signals are not used (Lorch 1989).

Finally, notes were also scored for the number of images contained (e.g., the image of a negatively skewed distribution). Each of the nine images presented during lecture was scored as full, partial, or absent. Using the example of a negatively-skewed distribution, a full image depicted its shape and identified where the mean, median, and mode fell in the distribution; a partial image perhaps included only the distribution shape; and an absent image meant that no image was recorded. In general, the presence of images in learning materials boosts achievement (Mayer 2009), but the noting of images did not prove beneficial in a recent text learning study (Fiorella and Mayer 2017). Interrater reliability, measured by Cohen's kappa, was .811 for full image scores and .870 for partial image scores. Disagreements were resolved by discussion. Because of the low number of full and partial images found in participants' notes, these two indices were combined into one index (i.e., the number of images recorded) for analysis.

Results

Results pertained to preliminary analyses, achievement, note taking, and attitudes.

Preliminary Analyses

Chi square tests were conducted for demographic variables, prior knowledge, typical note-taking completeness, and note-taking medium preference (all were categorical variables). Table 1 provides group statistics for these analyses. The four groups (laptop process, longhand process, laptop product, and longhand product) differed significantly on gender ($p = .13$) and on note-taking medium preference (longhand versus laptop; $p = .10$), using $p = .20$ significance level to avoid Type II errors. Based on these findings, gender and note-taking medium preference were included as covariates in all further analyses. The groups did not differ significantly with respect to the other demographic, prior knowledge, or typical note-taking completeness variables.

Achievement

Two-way MANCOVA—medium (laptop vs. longhand) by function (process vs. product)—was conducted on image-related and on text-related achievement scores. Image-related and text-related scores were moderately correlated, $r = .511$, $p < .001$. For interpretation purposes, effect sizes (i.e., eta squares) around .02 are small, around .13 are moderate, and around .26 are large (Cohen 1992).

The overall multivariate test revealed a statistically significant interaction effect of note-taking medium and note-taking function, $p = .022$, $\eta^2 = .062$, and a significant note-taking function main effect, $p = .013$, $\eta^2 = .071$, as well as a significant covariate: note-taking medium preference, $p = .024$, $\eta^2 = .061$. Table 2 provides multivariate test statistics for all

Table 1 Group statistics for demographic variables

	Laptop process	Laptop product	Longhand process	Longhand product	Chi square test	
	n (%)	n (%)	n (%)	n (%)	χ^2	p
Gender						
Male	10 (36)	6 (18)	5 (17)	4 (13)		
Female	18 (64)	28 (82)	25 (83)	28 (87)	5.74	.13
Class standing						
Freshman	1 (4)	0 (0)	0 (0)	0 (0)		
Sophomore	9 (32)	9 (27)	9 (31)	6 (18)		
Junior	7 (25)	14 (41)	5 (17)	13 (41)		
Senior	11 (39)	11 (32)	15 (52)	13 (41)	10.20	.34
Ethnicity						
White	27 (96)	33 (97)	27 (93)	30 (94)		
Black	1 (4)	0 (0)	2 (7)	0 (0)		
Hispanic	0 (0)	0 (0)	0 (0)	1 (3)		
Asian	0 (0)	0 (0)	0 (0)	1 (3)		
Other	0 (0)	1 (3)	0 (0)	0 (0)	12.46	.41
Overall GPA						
3.5–4.0	20 (71)	23 (68)	17 (57)	18 (56)		
3.0–3.4	4 (14)	8 (23)	7 (23)	12 (38)		
2.5–2.9	3 (11)	3 (9)	5 (17)	2 (6)		
2.0–2.4	0 (0)	0 (0)	1 (3)	0 (0)		
Below 2.0	1 (4)	0 (0)	0 (0)	0 (0)	12.50	.41
Prior knowledge						
Yes	16 (57)	25 (73)	20 (67)	22 (69)		
No	12 (43)	9 (27)	10 (33)	10 (31)	5.12	.53
Typical note-taking completeness						
Take a lot of notes	18 (64)	20 (61)	19 (63)	18 (56)		
Take a few notes	9 (32)	13 (39)	11 (37)	11 (35)		
Do not take notes	1 (4)	0 (0)	0 (0)	3 (9)	6.19	.40
Note-taking medium preference						
Prefer longhand	16 (57)	27 (79)	26 (87)	23 (72)		
Prefer laptop	12 (43)	7 (21)	3 (10)	8 (25)		
Prefer both	0 (0)	0 (0)	1 (3)	1 (3)	10.60	.10

variables, and the next two subsections address image-related and text-related findings, respectively.

Image-related achievement scores

There was an interaction between note-taking medium and note-taking function for image-related test scores after controlling for the covariates, $F(1, 120) = 7.328$, $p = .008$, $\eta^2 = .058$. With respect to the covariates, note-taking medium preference ($p = .006$, $\eta^2 = .061$) was

Table 2 Multivariate test statistics for achievement analysis

	Wilks' Λ	F(2, 119)	p value	Partial η^2
Covariates				
Gender	.977	1.388	.254	.023
Note-taking medium preference	.939	3.838	.024	.061
Main effects				
Note-taking function	.929	4.545	.013	.071
Note-taking medium	.991	.519	.599	.009
Interaction effect				
Note-taking function*medium	.938	3.965	.022	.062

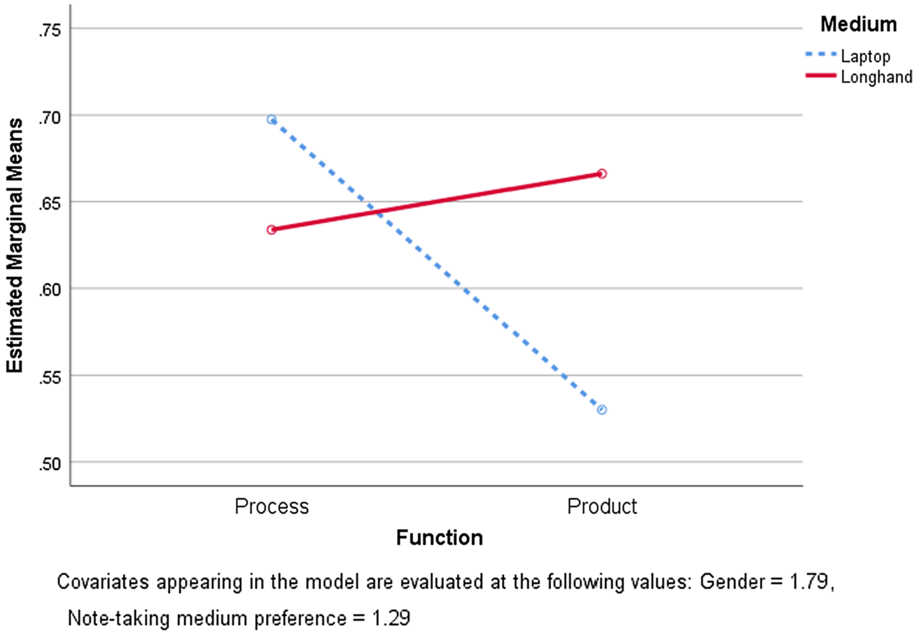

Fig. 1 Interaction of note-taking medium and function for image-related achievement scores

statistically significant, and gender ($p=.246$, $\eta^2=.011$) was not significant. The interaction pattern is depicted in Fig. 1, and the follow-up tests of simple effects were conducted. The interaction can be interpreted two ways. First, regarding the simple effect of note-taking function at each level of note-taking medium: when laptop notes were recorded, participants who only took notes without reviewing them ($M=70\%$, SD $=21\%$) outperformed those who took notes and reviewed them ($M=53\%$, SD $=18\%$) on image-related achievement items, $p=.002$, $\eta^2=.079$. When longhand notes were recorded, however, reviewing notes did not yield statistically different results from not reviewing them ($M=67\%$, SD $=24\%$ vs. $M=63\%$, SD $=19\%$, respectively), $p=.531$, $\eta^2=.003$. Second, regarding the simple effect of note-taking medium at each level of note-taking function: when notes were recorded but not reviewed (process function), the laptop group ($M=70\%$, SD $=21\%$) and the longhand group ($M=63\%$, SD $=19\%$) did not differ significantly on image-related

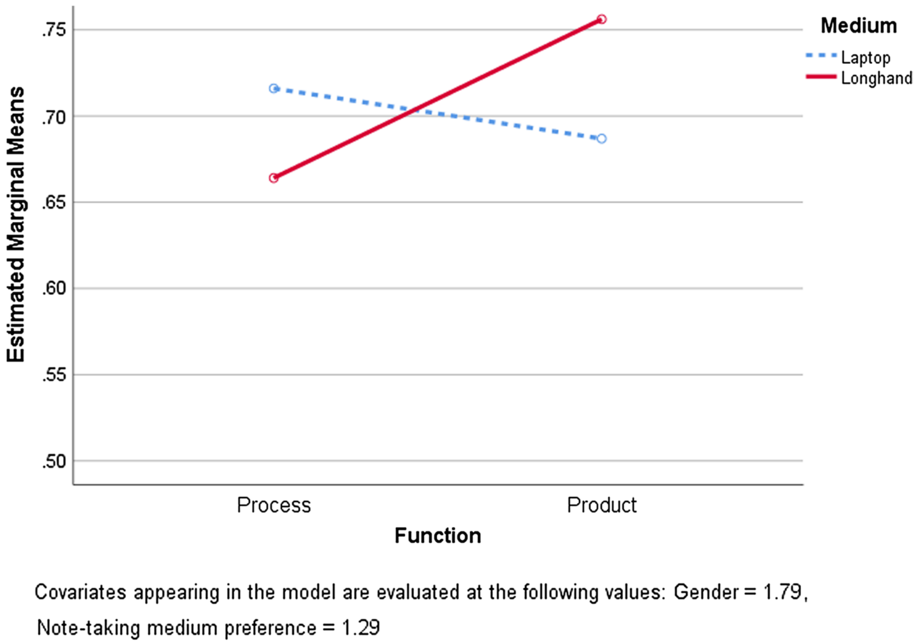

Fig. 2 Interaction of note-taking medium and function for text-related achievement scores

achievement items, $p=.241$, $\eta^2=.011$. When notes were both recorded and reviewed (product function), the longhand group ($M=67\%$, $SD=24\%$) outscored the laptop group ($M=53\%$, $SD=18\%$), $p=.007$, $\eta^2=.051$. The main effect for note-taking function was not significant, $F(1, 120)=3.452$, $p=.066$, $\eta^2=.028$. The main effect for note-taking medium was not significant, $F(1, 120)=.981$, $p=.324$, $\eta^2=.008$.

Text-related achievement scores

There was an interaction between note-taking medium and function for text-related test scores after controlling for the covariates, $F(1, 120)=4.361$, $p=.039$, $\eta^2=.035$. The covariates were not significant (gender, $p=.246$, $\eta^2=.011$; note-taking medium preference, $p=.170$, $\eta^2=.016$), so including them did not affect results. The interaction pattern is depicted in Fig. 2, and the follow-up tests of simple effects were conducted. The interaction can be interpreted two ways. First, regarding the simple effect of note-taking function at each level of note-taking medium: when laptop notes were recorded, reviewing notes or not reviewing notes did not differentially affect text-related achievement ($M=69\%$, $SD=15\%$ vs. $M=72\%$, $SD=15\%$, respectively), $p=.479$, $\eta^2=.004$. When longhand notes were recorded, however, students who reviewed notes ($M=76\%$, $SD=15\%$) outperformed those who only took notes but did not review them on text-related achievement ($M=66\%$, $SD=17\%$), $p=.025$, $\eta^2=.041$. Second, regarding the simple effect of note-taking medium at each level of note-taking function: when notes were recorded but not reviewed (process function), the laptop group ($M=72\%$, $SD=15\%$) had higher mean scores than the longhand group ($M=66\%$, $SD=17\%$), but the simple effect test was not significant, $p=.224$, $\eta^2=.012$. When notes were both recorded and reviewed (product function), the longhand group ($M=76\%$, $SD=15\%$) had higher mean scores than the laptop group ($M=69\%$,

Table 3 Mean (and standard deviations) of outcome variables by groups

	Laptop process ($n = 30$)	Longhand process ($n = 30$)	Laptop product ($n = 34$)	Longhand product ($n = 32$)
Achievement				
Image-related	70% (21%)	63% (19%)	53% (18%)	67% (24%)
Text-related	72% (15%)	66% (17%)	69% (15%)	76% (15%)
Note taking index				
Verbatim notes	.52 (1.11)	− .35 (.90)	.26 (.92)	− .43 (.76)
Note quantity	.23 (1.19)	− .26 (.72)	.31 (1.07)	− .31 (.83)
Visual notes	− .72 (.39)	.91 (.75)	− .80 (.37)	.67 (.88)
Attitude				
Effective	4.23 (1.28)	4.43 (1.07)	3.76 (1.25)	4.34 (1.08)
Easy to use	5.00 (1.20)	4.20 (1.38)	4.73 (1.18)	4.45 (1.18)
Enjoyable	4.43 (1.28)	3.70 (1.37)	4.18 (1.51)	3.79 (1.08)
Future use	4.57 (1.48)	4.60 (1.50)	4.00 (1.50)	4.45 (1.50)

Covariates values: Gender = 1.79, Note-taking medium preference = 1.29

SD = 15%), but the simple effect test was not significant either, $p = .079$, $\eta^2 = .025$. The main effects for note-taking function [$F(1, 120) = 1.214$, $p = .273$, $\eta^2 = .010$] and for note-taking medium [$F(1, 120) = .091$, $p = .764$, $\eta^2 = .001$] were not significant.

In summary, across both achievement measures, the process function of note taking was more beneficial than the product function of note taking when students took laptop notes (i.e., better image-related learning and similar text-related learning). On the other hand, the product function of note taking was more beneficial than the process function of note taking when students took longhand notes (i.e., better text-related learning and similar image-related learning). The top portion of Table 3 provides group means and standard deviations for all achievement scores.

Note Taking

Because there were seven note-taking variables examined (i.e., idea units, words, verbatim strings (one-, two-, and three-word strings), signals, and images), a principal components analysis (PCA) was used to reduce the number of variables and to compute proper composite scores. The note-taking data met the assumptions for using PCA. First, these note-taking variables were correlated as shown in the Table 4 correlation matrix. Second, sample size ($n = 126$) was adequate, providing a ratio of 18 observations per variable. The Kaiser–Meyer–Olkin measure of Sampling Adequacy was 0.57, and the Bartlett's test of sphericity was statistically significant ($\chi^2(21) = 702.12$, $p < .001$). Furthermore, each note-taking variable shared some common variance with other variables (all communalities were above 0.6).

PCA results showed that the first three eigenvalues were above one. The first three components explained 45, 25, and 14% of variance, respectively. Therefore, a three-factor solution that explained 84% of the variance was adopted. Direct oblimin rotation was used to allow correlation between note-taking components. As shown in the pattern matrix (Table 5), the first component included the three verbatim string indices, the second

Table 4 Correlation coefficients between note-taking measures

	Idea units	Words	Verbatim strings			Signals	Images
			1-word	2-word	3-word		
Idea units	1.00	0.67**	– 0.19*	– 0.21*	– 0.17	0.23*	0.16
Words		1.00	– 0.08	0.24**	0.31**	– 0.19*	– 0.34**
1-word			1.00	0.70**	0.57**	– 0.22*	– 0.15
2-word				1.00	0.97**	– 0.45**	– 0.44**
3-word					1.00	– 0.46**	– 0.47**
Signals						1.00	0.41**
Images							1.00

**Correlation is significant at the 0.01 level

*Correlation is significant at the 0.05 level

Table 5 Pattern matrix for principal components analysis on note-taking variables

	Component 1 Verbatim notes	Component 2 Note quantity	Component 3 Visual notes
One-word verbatim strings	.957		
Two-word verbatim strings	.873		
Three-word verbatim strings	.786		
Idea units		.923	
Words		.901	
Images			.839
Signals			.773

Loadings < .4 are suppressed

component included idea units and words, and the third component included noted signals and images. Therefore, the first component was labeled "Verbatim Notes Index," the second component was labeled "Note Quantity Index," and the third component was labeled "Visual Notes Index."

To assess the effects of note-taking medium (laptop vs. longhand) and note-taking function (process vs. product) with regard to these three note indices, a 2 × 2 MANCOVA was conducted and included participants' gender and note-taking medium preference for laptop or longhand note taking as covariates. The overall multivariate test revealed a statistically significant main effect for note-taking medium, $p < .001$, $\eta^2 = .661$. The interaction effect was not significant, $p = .939$, $\eta^2 = .003$, and neither was the main effect for note-taking function, $p = .305$, $\eta^2 = .030$. With respect to the covariates, gender was significant, $p < .001$, $\eta^2 = .153$. Note-taking medium preference was not significant, $p = .499$, $\eta^2 = .020$. Table 6 provides multivariate test statistics for all variables, and specific findings for the three note indices are addressed next in turn.

With respect to Verbatim Notes Index, there was a significant main effect for note-taking medium: laptop note takers ($M = .38$, SD = 1.02) had higher scores than longhand note takers ($M = -.39$, SD = .90), $p < .001$, $\eta^2 = .141$, meaning that laptop note takers recorded more verbatim strings than longhand note takers as measured by one-, two-, and three-word

Table 6 Multivariate test statistics for notes analysis

	Wilks' Λ	F (3, 118)	p value	Partial η^2
Covariates				
Gender	.847	7.086	< .001	.153
Note-taking medium preference	.980	.795	.499	.020
Main effects				
Note-taking function	.970	1.222	.305	.030
Note-taking medium	.339	76.819	< .001	.661
Interaction effect				
Note-taking function*medium	.997	.135	.939	.003

strings. The main effect for note-taking function ($p = .428$, $\eta^2 = .005$) and the interaction effect ($p = .572$, $\eta^2 = .003$) were not significant. The covariates were not significant (gender: $p = .085$, $\eta^2 = .025$ and note-taking medium preference: $p = .411$, $\eta^2 = .006$).

With respect to Note Quantity Index, there was a significant main effect for note-taking medium: laptop note takers ($M = .27$, SD = 1.11) had higher scores than longhand note takers ($M = -.28$, SD = .78), $p < .001$, $\eta^2 = .120$, after controlling for the covariates, meaning that laptop note takers recorded more notes than longhand note takers as measured by idea units and words. The gender covariate was significant ($p < .001$, $\eta^2 = .145$), but the note-taking medium preference covariate was not significant ($p = .990$, $\eta^2 = .000$). The main effect for note-taking function ($p = .573$, $\eta^2 = .003$) and the interaction effect ($p = .974$, $\eta^2 = .000$) were not significant.

With respect to Visual Notes Index, there was a significant main effect for note-taking medium: longhand note takers ($M = .78$, SD = .82) had higher scores than laptop note takers ($M = -.76$, SD = .38), $p < .001$, $\eta^2 = .588$ after controlling for the covariates, meaning that longhand note takers recorded more visual notes, comprised of signals and images, than laptop note takers. The covariates, gender ($p = .346$, $\eta^2 = .007$) and note-taking medium preference ($p = .230$, $\eta^2 = .012$), were not significant. The main effect for note-taking function ($p = .107$, $\eta^2 = .021$) and the interaction effect ($p = .751$, $\eta^2 = .001$) were not significant.

Overall, laptop note takers recorded more notes and more verbatim notes than longhand note takers who, in turn, recorded more visual notes than laptop note takers. The middle portion of Table 3 provides group means and standard deviations for all note-taking indices.

Attitudes

Participants rated their attitudes about their experimental note-taking medium (laptop or longhand) in terms of effectiveness, ease of use, enjoyment, and likelihood of future use using a 1–6 Likert-type scale (1 = To a small degree, 6 = To a large degree). A 2 × 2 MANCOVA was conducted and included participants' gender and note-taking medium preference for laptop or longhand note taking as covariates. The overall multivariate test revealed a statistically significant main effect for note-taking medium that favored the process group, $p < .001$, $\eta^2 = .204$. The interaction effect was not significant, $p = .689$, $\eta^2 = .020$, and neither was the main effect for note-taking function, $p = .262$, $\eta^2 = .045$. With respect to the covariates, none were significant. Table 7 provides multivariate test statistics for all variables.

Table 7 Multivariate test statistics for attitudes analysis

	Wilks' Λ	F (4, 113)	p value	Partial η^2
Covariates				
Gender	.976	.682	.606	.024
Note-taking medium preference	.964	1.057	.381	.036
Main effects				
Note-taking function	.955	1.333	.262	.045
Note-taking medium	.796	7.228	< .001	.204
Interaction effect				
Note-taking function*medium	.980	.564	.689	.020

With respect to effectiveness, laptop ($M = 3.98$, SD = 1.28) and longhand ($M = 4.39$, SD = 1.07) groups did not differ significantly, $p = .136$, $\eta^2 = .019$. With respect to ease of use, there was a significant main effect for note-taking medium: laptop note takers rated their note-taking medium easier to use ($M = 4.86$, SD = 1.19) than longhand note takers ($M = 4.32$, SD = 1.28), $p = .022$, $\eta^2 = .045$. With respect to enjoyment, laptop note takers ($M = 4.30$, SD = 1.40) enjoyed taking notes using their medium more than longhand note takers did using their medium ($M = 3.75$, SD = 1.23), $p = .028$, $\eta^2 = .041$. Finally, with respect to future use, laptop ($M = 4.27$, SD = 1.51) and longhand ($M = 4.53$, SD = 1.49) note takers did not differ significantly, $p = .479$ $\eta^2 = .004$.

Overall, participants found the laptop note-taking method easier to use and more enjoyable than the longhand method. The bottom portion of Table 3 provides group means and standard deviations for all attitude measures.

Discussion

With the growing popularity of laptop use in classrooms (Fried 2008; Lauricella and Kay 2010), investigating the effectiveness of laptop note taking versus traditional longhand note taking is important. Yet, research on this topic is still in its infancy because, as far as we know, only three other published studies have investigated laptop versus longhand note taking for classroom learning (Bui et al. 2013; Fiorella and Mayer 2017; Mueller and Oppenheimer 2014). The present study makes important contributions to this research domain. First, the present study investigated systematically the main and interactive effects of note-taking function (process, product) and medium (laptop, longhand) on college students' note taking and achievement, a research direction taken in just one other experiment (Mueller and Oppenheimer 2014, Experiment 3). Second, it examined these variables using material that was more authentic than the non-course material used in previous studies (Bui et al. 2013; Mueller and Oppenheimer 2014) or than text material printed on flashcards (Fiorella and Mayer 2017). Third, the present study investigated a variety of note-taking behaviors (i.e., idea units, words, verbatim strings, and signals) and was the first to examine how students record notes on images presented in a lecture and how recording such images affects image-related achievement. Previous research on noted images (Fiorella and Mayer 2017) involved text learning, and images were not actually included in the text materials.

The present study's main purpose was investigating systematically the main and interactive effects of note-taking function (process, product) and medium (laptop, longhand) on college students' achievement and note taking, with a unique focus on how students take notes when a lecture contains visual images. Therefore, achievement was based on image-related achievement scores and on text-related (non-image) achievement scores. With respect to image-related achievement, laptop note takers benefited more from note taking's process function than product function, whereas longhand note takers benefited equally from both functions. With respect to text-related achievement, laptop note takers benefited equally from both functions, whereas longhand note takers benefited more from note taking's product function than process function.

Both achievement results can be explained by the nature of recorded notes. Laptop note takers recorded more notes (idea units and words) and more verbatim notes than longhand note takers who, in turn, recorded more visual notes, in the form of signals and images, than laptop note takers. Our contention is that laptop note takers had a transcription orientation and recorded mainly verbal information from the lecture (Mueller and Oppenheimer 2014), whereas longhand note takers had a generative orientation and used a combination of verbal and spatial note-taking strategies (Armbruster 2000; Bohay et al. 2011; Fiorella and Mayer 2017; Reimer et al. 2009). The benefit of transcription-oriented laptop note taking was that it required minimal cognitive processing—students seemed to simply copy what they heard—compared to generative-oriented longhand note taking, where students devoted extra resources to paraphrasing lecture ideas, drawing complex images, and signaling important ideas. The spending of additional resources purportedly limited longhand note takers' learning during the note-taking process (see Kiewra et al. 1991) and likely led to their lower image-related achievement scores compared to laptop note takers when tested without review.

The more generative-oriented longhand note-taking medium was more beneficial than laptop note taking once notes were reviewed as observed for text-related achievement. Although recording paraphrased and visual notes hindered learning without an opportunity for review, such notes proved effective once they were reviewed. When there was ample processing time during review, the more generative longhand notes proved to be a better review source than the more transcription-oriented laptop notes. Longhand note takers might have particularly benefited from having images in their notes to review. Laptop note takers, meanwhile, had no images to review and, consequently, their image-related achievement scores were lower following review than when there was no review.

Looking across note-taking and achievement findings from the present study and three others (Bui et al. 2013; Fiorella and Mayer 2017; Mueller and Oppenheimer 2014) investigating laptop and longhand note taking, some commonalities and differences emerge as shown in Table 8, where present findings appear in the fourth column. Regarding commonalities, first, all four studies found that laptop notes contained more information (idea units and/or words) or verbatim strings than longhand notes as shown in the top portion of Table 8. These reoccurring findings indicate that taking notes with a laptop prompts transcription-oriented note taking (Fiorella and Mayer 2017; Mueller and Oppenheimer 2014). Second, two studies (present study and Fiorella and Mayer 2017) examining noted images found that longhand notes contained more images than laptop notes. These similar findings suggest that taking longhand notes prompts generative note taking and spatial strategy use. Recording image notes, however, did not boost image-related achievement scores. As shown in the bottom portion of Table 8, both studies found that laptop note takers outperformed or performed comparably to longhand note takers.

Regarding differences, there was inconsistency among the studies regarding achievement as shown in the middle portion of Table 8. With respect to text-related achievement scores, one study (Bui et al. 2013, Experiment 1) found a process advantage for laptop

Table 8 Four studies comparing laptop versus longhand note taking

	Bui et al. (2013)	Mueller and Oppenheimer (2014)	Fiorella and Mayer (2017)	Present study
Note taking				
Idea units and words	Laptop > Longhand	Laptop > Longhand	Laptop > Longhand	Laptop > Longhand
Verbatim strings	Laptop > Longhand	Laptop > Longhand	–	Laptop > Longhand
Signals and images	–	–	Longhand > Laptop	Longhand > Laptop
Achievement				
Text-related				
When notes were not reviewed	Laptop > Longhand	Longhand > Laptop	–	Longhand = Laptop
When notes were reviewed	–	Longhand > Laptop	Laptop > Longhand	Longhand > Laptop
Image-related				
When notes were not reviewed	–	–	–	Laptop > Longhand
When notes were reviewed	–	–	Laptop > Longhand	Laptop = Longhand

note taking over longhand note taking, whereas another study (Mueller and Oppenheimer 2014), found a process advantage for longhand note taking over laptop note taking (in two of three experiments). In the present study, laptop and longhand note takers did not differ from one another with regard to note taking's process function. These mixed findings add to the already mixed findings regarding the process function of note taking (Kiewra 1985; Kobayashi 2005) and leave unclear whether recording laptop or longhand notes is best when notes are not reviewed. This lack of clarity might not hold much practical importance, though, given that the primary reason for recording notes is producing a complete and effective set of notes for review (Badger et al. 2001; Kiewra 1985; Van Etten et al. 1997).

When notes were reviewed (product function), two studies (present study and Mueller and Oppenheimer 2014) found an advantage for reviewing longhand notes over laptop notes, but Fiorella and Mayer's study (2017) revealed the opposite. The difference in the reviewing effect might be associated with review period length: the present study and Muller and Oppenheimer's study (15 and 10 min, respectively) had longer review periods than Fiorella and Mayer's study (3 min).

Limitations, Future Research Directions, and Educational Implications

Some present study limitations and corresponding future research directions are noteworthy. The first pertains to randomization. Although assigning participants to note-taking groups randomly can result in nearly equitable groups, as was the case in the present study, doing so might run counter to participants' note-taking medium preference and thereby mask naturally occurring results. In the present study, for example, 75% of participants reported that they commonly take notes longhand, whereas just 25% reported that they commonly take notes using a laptop (see Table 1). This was taken into consideration by including note-taking medium preference as a covariate in analyses. Still, future studies could investigate longhand and laptop note taking in more natural settings that allow students to take notes using their preferred medium as Friedman et al. (2014) did.

A second limitation pertains to low levels of recorded images in notes. On average, longhand note takers recorded one lecture image in notes, whereas laptop note takers recorded none of the nine lecture images in notes. One explanation for this small number of recorded images might be that images were presented in the last section of the lecture when attention is likely to wane (Scerbo et al. 1992). Alternatively, lecture rates that exceed students' transcription rates might generally cause students to abandon image recording throughout the lecture in favor of recording verbal information. Because image-related note taking research is in its infancy, there are several avenues that future image-related studies might pursue including: (a) varying the number of images provided, (b) varying how images are spread throughout the lecture, (c) varying lecture pace or lecture pauses, (d) varying whether or not images are supplemented by verbal descriptions as occurred in the present study, and (e) examining the potential of laptop note taking when users can use the laptop's camera to capture a lecture's displayed images.

A third limitation is that testing only occurred immediately following the lecture. Although many previous studies examined note-taking functions in this way (e.g., Kiewra et al. 1991; Peverly et al. 2007), adding a delayed test is more comparable to what happens in actual classroom settings and is more likely to magnify any laptop versus longhand achievement differences especially when notes are reviewed.

A fourth limitation pertains to the uneven instructions for the note-taking function groups. Prior to the experiment, both the note-taking process and the note-taking product groups were informed of a post-test, but the product group received an additional instruction indicating they would have a 15-min period for reviewing their notes before the test. Knowing they would have a review period might have differentially affected the product group's note-taking behaviors in relation to those of the process group (who received no such instruction). Although this did not appear to be the case given that the 2×2 MANCOVA on notes showed that the process and product groups did not differ in their note-taking behaviors (i.e., note-taking function main effect was not significant), future studies should avoid this potential confounding factor by providing consistent instructions to both note-taking function groups.

A final limitation is that only one lecture was used, which limited findings' generalizability. Future studies might use multiple lectures to improve generalizability as Mueller and Oppenheimer (2014) did.

Some educational implications follow from this and related studies. First, despite the growing popularity of laptop note taking (Fried 2008; Lauricella and Kay 2010) and students' self-reports that laptop note taking is beneficial (e.g., Barak et al. 2006; Mitra and Steffensmeier 2000; Skolnick and Puzo 2008) and is easier and more enjoyable than longhand note-taking (present study), laptop note taking has limitations. First, laptop note-taking discourages students from recording lecture images in their notes. Therefore, laptops might not be the ideal medium for recording notes when lectures contain several important images. Second, reviewing laptop notes is generally less beneficial than reviewing longhand notes, which are more paraphrased, contain more signals and images, and lead to higher text-related achievement when reviewed. Despite these findings, the present study cannot confirm that such note taking is best for those who prefer to record laptop notes. Previous laptop note-taking research (Bui et al. 2013) showed that verbatim transcription resulted in higher achievement than recording organized notes for immediate testing without review (Experiment 1) and for delayed testing following note review (Experiment 3), but not for delayed testing when notes were not reviewed (Experiment 2). Taken together, it seems that laptop note taking lends itself to verbatim note taking (Bui et al. 2013; Mueller and Oppenheimer 2014; and the present study) and that verbatim laptop note taking is effective when testing occurs immediately without review and when testing is delayed following review.

Second, when incorporating images in their lectures, instructors should take steps to be sure such images are recorded in notes and later reviewed. Previous note-taking research suggests that this can occur when instructors simply provide students with notes containing images (Bui and McDaniel 2015; Stefanou et al. 2008), slow the lecture rate to allow more complete note taking (Aiken et al. 1975), or provide pauses likely to increase note taking (Luo et al. 2016).

Third, instructors should warn students, especially those using laptops, not to simply transcribe notes because such shallow processing does not always boost achievement. A mild warning, though, might not be sufficient to deter laptop note takers from "mindless transcription" (Mueller and Oppenheimer 2014, p. 1166).

In conclusion, different note-taking mediums promote different note-taking strategies. Laptop use promotes a transcription-oriented verbatim-style note taking that contains mostly verbal information. This transcription style allows laptop note takers to record more or longer notes than longhand note takers. Longhand note takers, on the other hand, use a generative note-taking approach and produce notes that are more paraphrased and more visual (containing more signals and images). The full benefit of longhand notes, however, is only realized when those notes are reviewed.

Acknowledgment We thank Dr. Pam Mueller and Dr. Daniel Oppenheimer for supplying the program for the verbatim strings analyses, and we thank Daniel Parr for scoring notes.

Appendix: Examples of the narrated PowerPoint lecture slides

See Figs. 3 and 4.

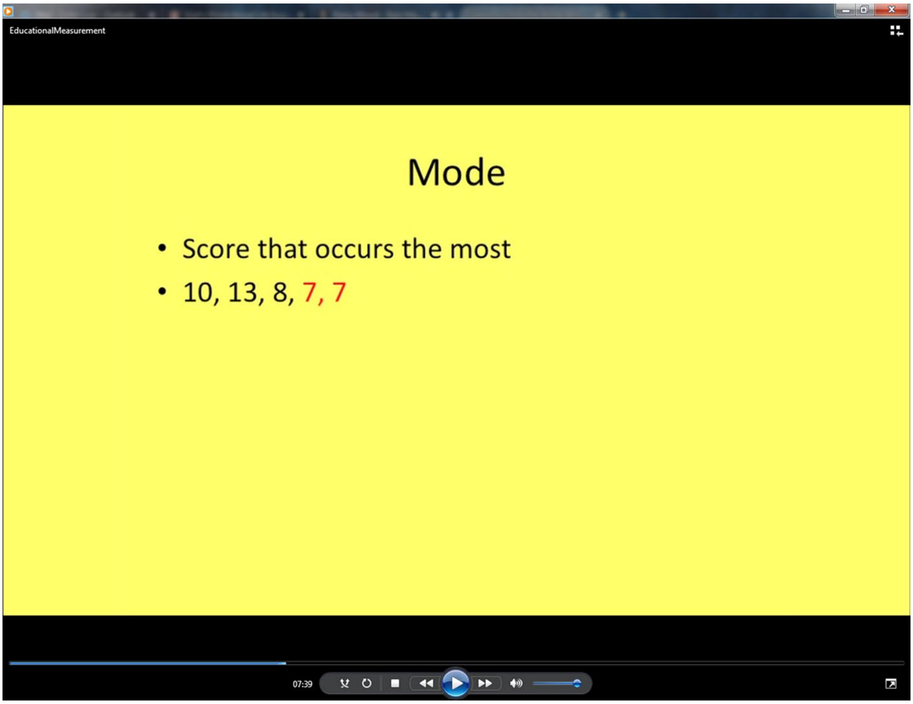

Fig. 3 Sample lecture slide with verbal information only

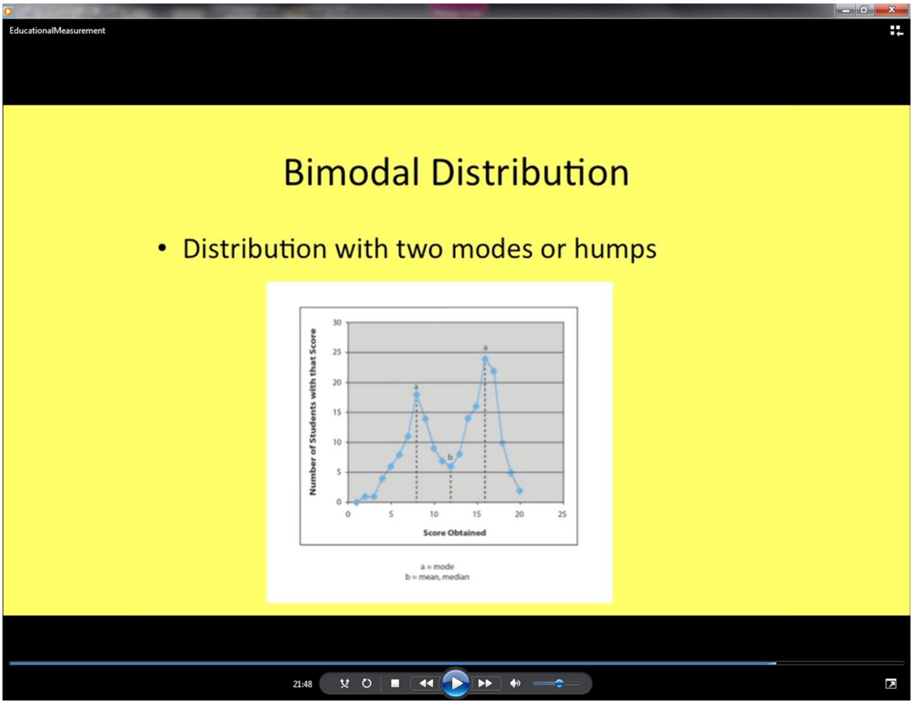

Fig. 4 Sample lecture slide with verbal information and image

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