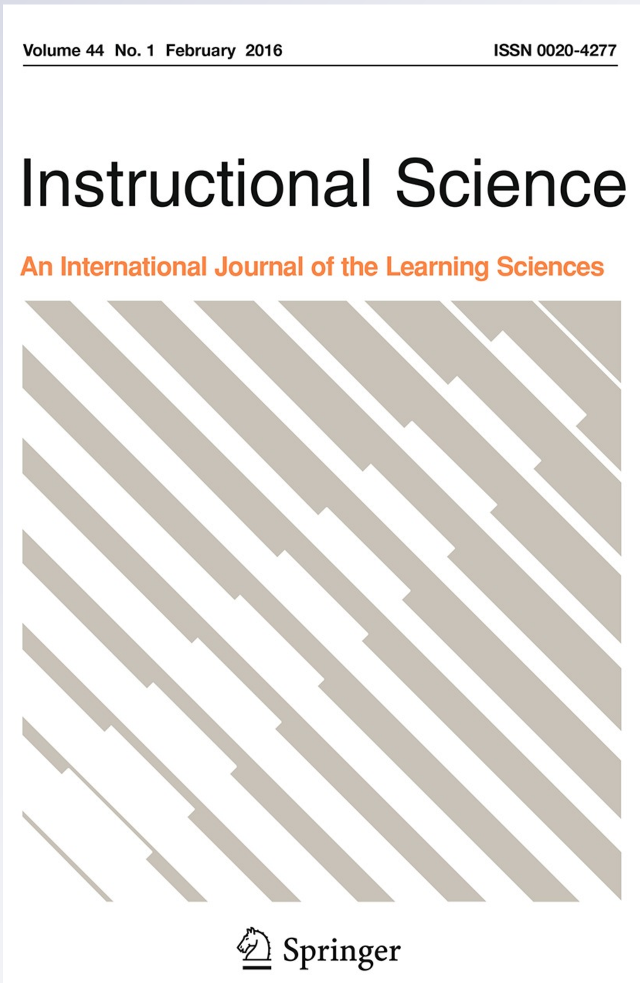
Revising lecture notes: how revision, pauses, and partners affect note taking and achievement

Linlin Luo, Kenneth A. Kiewra & Lydia Samuelson

Instructional Science
An International Journal of the Learning Sciences

ISSN 0020-4277
Volume 44
Number 1

Instr Sci (2016) 44:45-67
DOI 10.1007/s11251-016-9370-4



Instr Sci (2016) 44:45–67
DOI 10.1007/s11251-016-9370-4

Revising lecture notes: how revision, pauses, and partners affect note taking and achievement

Linlin Luo[1] · Kenneth A. Kiewra[1] · Lydia Samuelson[1]

Received: 29 June 2015 / Accepted: 19 January 2016 / Published online: 25 January 2016

Abstract Note taking has been categorized as a two-stage process: the recording of notes and the review of notes. We contend that note taking might best involve a three-stage process where the missing stage is revision. This study investigated the benefits of revising lecture notes and addressed two questions: First, is revision more effective than non-revision? Second, what revision method is best? Experiment 1 addressed the first question by comparing the performance of participants who revise or recopy lecture notes. Experiment 2 addressed the second question by investigating whether revision was best done (a) during pauses throughout the lecture or one equally-timed pause after the lecture, and (b) with a partner or alone. Dependent measures were original and additional notes and fact and relationship test scores. Results upheld three effects: (a) a modest revision effect—revisers recorded more additional notes and achieved somewhat higher scores on relationship items than re-copiers, (b) a pause effect—those revising during pauses outperformed those revising after the lecture on the notes and achievement measures, and (c) a modest partner effect—those revising with partners recorded more original notes than those revising alone. Furthermore, the combination of pauses and partners has merit and holds promise as a means for revision. Overall, findings suggested that revision is a new student-centered means to boost lecture note taking and achievement.

Keywords Note taking · Note revision · Lecture pauses · Collaborative learning · Achievement

Despite recent advancements in instructional technology, lecture remains the dominant instructional format in most college classrooms (Exley and Dennick 2009; Maydosz and

✉ Linlin Luo
lluo@huskers.unl.edu

[1] Department of Educational Psychology, University of Nebraska-Lincoln, Lincoln, NE 68588-0345, USA

Raver 2010; Watts and Becker 2008). Meanwhile, most college students today still record notes during lectures (Bonner and Holliday 2006; Castello and Monereo 2005) and prefer to take notes by hand rather than by computer because they believe that hand written notes allow greater flexibility for signaling important ideas and for creating diagrams and other graphic organizers (Reimer et al. 2009; Schoen 2012). A recent study confirmed the benefits of hand written notes. Students who took hand written notes outperformed those who took laptop notes (Mueller and Oppenheimer 2014).

It is good that students still value note taking because both the process of recording notes (versus listening only) and the product reviewed (versus no review) raise fact and relationship learning (e.g., Kiewra 1985a, 1989a). The process value of note taking is attributed to increased attention during the lecture (e.g., Katayama and Crooks 2003; Kobayashi 2006; Piolat et al. 2005), whereas the product value is attributed to meaningful processing during review following the lecture (e.g., Armbruster, 2000; Crooks et al. 2007). It is also good that students value note taking because the more paraphrased notes students record, the higher their achievement (Peverly et al. 2003; Williams and Worth 2002). There is, however, a problem. Students are incomplete note-takers and normally record just one third of important lecture points (Austin et al. 2004; Titsworth 2004). When key points are omitted from notes, there is only about a 5 % chance of students recalling those missing points when tested (Einstein et al. 1985; Howe, 1970). Naturally, researchers have investigated ways to increase lecture note completeness.

Methods for increasing lecture notes

Four proven methods for increasing note completeness are (a) providing full notes, (b) providing skeletal notes, (c) providing lecture cues, and (d) re-presenting the lecture.

One obvious means for bolstering notes is for instructors to give students a full set of notes to review (Grabe 2005; Stefanou et al. 2008). In one representative study (Kiewra 1985b), college students, during the acquisition phase, listened to a lecture, recorded notes during the lecture, or absented themselves from the lecture. Two days later, during the review phase, they studied their own notes, a set of full notes provided by the instructor, both sets of notes, or no notes (depending upon condition). Results showed that groups that studied full notes achieved most regardless of their acquisition condition. This was because students' own notes contained just 35 % of important lecture points compared to 100 % for full notes.

A related means for bolstering lecture notes is providing a skeletal outline that presents the lecture's main points with spaces below for recording lecture details (Konrad et al. 2009; Raver and Maydosz 2010). In one such study (Kiewra et al. 1995), college students viewed a lecture on creativity and took notes on blank paper or on a skeletal outline. Those recording notes on blank paper noted 38 % of lecture points, whereas those using the skeletal outline noted 56 % of lecture points. A more recent study (Austin et al. 2004) also found that participants given skeletal notes recorded more lecture information than those without skeletal notes.

A third instructional strategy for increasing lecture notes is providing organizational lesson cues (Titsworth 2004). Organizational cues alert students to the organization of the lecture and to where lecture points fit within that organization. In a study examining organizational cues (Titsworth and Kiewra 2004), college students listened to one of two versions of a lecture about communication theories: cued and un-cued. Both versions were well organized and identical with one exception: the cued version signaled the lesson's organization by emphasizing one of the four lesson topics (e.g., mass communication) and one of the five lesson categories (e.g., description) each time a corresponding lesson point was presented. Students receiving organizational cues noted more of the lecture's organizational points (54 %) and details (80 %) than those not receiving cues (15 and 37 %, respectively).

Another method to bolster notes is re-presenting the lecture. In one study (Kiewra et al. 1991), college students recorded notes while watching a brief videotaped lecture presented one, two, or three times. All three groups noted a high percentage (80 %) of the lecture's main ideas but differed in noting lecture details. The one-presentation group recorded about 35 % of details, whereas the two- and three-presentation groups recorded about 50 and 60 % of details, respectively.

The four proven methods for increasing note taking share a common limitation. All involve instructor-provided materials or are instructor controlled. Such studies do not suggest avenues that students might take to improve their note taking. The present study addressed this limitation by examining a more student-controlled means for increasing note taking: revision.

Revision: the missing link

Note-taking researchers have historically categorized note taking as a two-stage process: the recording (transcription) of notes and the review (reading or studying) of notes (Di Vesta and Gray 1972; Kiewra 1985a; Kobayashi 2006). All of the studies reviewed in the earlier section, for example, helped students record (or simply gave them) a fuller set of notes to later review. We contend that note taking might best involve a three-stage process where the missing stage is revision. After notes are recorded, students might benefit from a brief revision period wherein they make changes to existing notes by adding to them to make them more complete and understandable. To be clear, revision differs from review in that the former process strives to add information to existing notes, whereas the latter process strives to commit noted information to memory. The prospect of revision seems warranted for two reasons: one based on overcoming lecture processing demands and the other based on improving information processing. First, in terms of lecturing processing demands, most college students are not equipped physiologically to record complete lecture notes (Bassili and Joordens 2008; Bui and Myerson 2014; Peverly et al. 2013). Although adults can listen at a rate of about 210 words per minute (Omoigui et al. 1999), a level greater than the pace of most lectures—about 100–125 words per minute (Wong 2014), adults can only write at a rate of about 22 words per minute (Brown 1999). College students, meanwhile, only type lecture ideas at a rate of about 33 words per minute (Karat et al. 1999). A revision period would partially counteract the processing demands of lectures by allowing students more time to add to existing notes before reviewing them.

Second, in terms of improved information processing, revision might serve a retrieval function (Roediger 2000; Thomson and Tulving 1970) wherein notes recorded during lecture help students retrieve and record additional lecture ideas not originally noted (Williams and Eggert 2002). For example, suppose a psychology lecturer reports the following: "Short-term memory has a limited capacity compared to long-term memory. It holds about seven items at a time. This might be why zip codes and phone numbers are seven or fewer digits long." Now suppose that a student wrote this in notes: "short-term memory holds about seven things." If the student is given a chance to revise, then this original note might cue the student to retrieve and note related lecture information such as, "short-term memory is more limited than long-term memory" and "phone numbers and zip codes are brief to accommodate short-term memory."

Retrieval, by way of revision, might do more than boost note completeness; it might enhance learning and boost achievement directly. In one representative study (Karpicke et al. 2009), students (a) reviewed a text four times, (b) reviewed it three times and then practiced retrieving text material the final time, (c) or reviewed it once and then practiced retrieving text material three times. The retrieval groups achieved more than the review-only group. Long-term retention for the review-only group was 15 %, but was 34 % for the one-retrieval group and 80 % for the repeated retrieval group. According to Karpicke (2012), retrieval aids learning because each act of retrieval enhances the value of retrieval cues and improves one's ability to retrieve knowledge in the future. Karpicke (2012) concluded that retrieval could be integrated into many learning activities, including lectures.

In summary, because recording speed lags well behind lecture speed and because notes might serve a retrieval function, revision seems to be a useful process for increasing noted ideas and boosting achievement. Moreover, revision is a more student-controlled note-improvement strategy than the instructor-controlled strategies like note provision (Grabe 2005) or cuing (Titsworth and Kiewra 2004) that are commonly investigated. To this point, though, there has been little investigation of revision. No study has investigated revision systematically by comparing revision with no revision, and a survey of students' study strategies yielded no evidence of revising lecture notes (Jairam and Kiewra 2010). Instead, students commonly recopy notes between lectures and review (Aharony 2006; Jairam and Kiewra 2010).

Revision methods

The most basic way for students to revise lecture notes is to do so after the lecture and on their own. But, that is not the only way. Revision might take place during lecture pauses (instead of after the lecture) and with a partner (instead of alone). Although no previous research has investigated these factors during the revision process, research indicates that pauses and partners aid the note-taking and review processes and might aid the revision process as well.

With respect to pauses, inserting them in lectures for purposes of taking or reviewing notes is advantageous (see Boyle, 2007). With respect to inserting pauses for taking notes, Aiken et al. (1975) had students take notes during lecture segments or during pauses between lecture segments. Although the two note-taking groups recorded comparable notes, the notes-during-pauses group scored higher on a delayed memory test and recalled a higher percentage of noted ideas than did the notes-during-lecture-segments group. With respect to inserting pauses for reviewing notes, Di Vesta and Gray (1973) had students either take notes during lecture segments and then review them during lecture pauses or take no notes during lecture segments and then review mentally during lecture pauses. Those who took notes during lecture segments and reviewed them during lecture pauses achieved most.

From a theoretical perspective, lecture pauses might be effective because they promote distributed learning, which involves breaking a massed learning episode into smaller parts.

The investigation of distributed versus massed learning originated with Ebbinghaus (1885/1964) and Thorndike (1912) and is still active today. Recent reviews and investigations (e.g., Cepeda et al. 2006; Stringfellow and Miller 2005) confirm that distributed learning produces higher achievement than massed learning probably because distributed learning relative to massed learning aids (a) attention—attention is better maintained across brief segments versus longer ones, (b) encoding—more associative links are made, and (c) consolidation—more time is available for information to consolidate (take hold) in memory.

With respect to partners, lecture-learning research stems from collaborative learning theory rooted in the social learning ideas of Vygotsky (1962). Collaborative learning is a situation in which two or more people attempt to learn something together while capitalizing on one another's resources and skills (Bruffee 1999). Collaborative learning generally works (Mitnik et al. 2009) because there is social responsibility to perform (Gillies 2004; Johnson and Johnson 1999) and because meaningful processing is more likely when individuals confer with partners (Delgado-Tellez and Raposo 2011). According to Chi's Interactive-Constructive-Active–Passive (ICAP) model (Chi and Wylie 2014), however, collaboration only enhances learning when partners truly interact and jointly construct meaning. Without meaningful collaboration, there is often no advantage for collaboration over individual learning (Barron 2003; Yetter et al. 2006).

Research on collaborative learning in note taking is mixed. With respect to the encoding function of note taking, some research showed that recording lecture notes with a partner led to more note taking than recoding notes alone and to improved learning (e.g., Kam et al. 2005), but other research did not find note-taking collaboration helpful (e.g., Aitken and Hatt 2012). With respect to the storage function, reviewing lecture notes with a partner was more advantageous than reviewing alone in one study (O'Donnell and Dansereau 1993) but no more advantageous than reviewing alone in another study (Lambiotte et al. 1993).

When it comes to revising notes, there might be two types of collaborative learning: simple note sharing (e.g., "I didn't have that point in notes, let me write it down"), and collaborative retrieval (e.g., "Okay, we both noted the definition, but wasn't there an example? Let's try to recall that and add it to notes."). According to the ICAP model (Chi and Wylie 2014), simple note sharing might boost the quantity of recorded notes, but collaborative retrieval might directly improve learning because it is interactive and constructive.

Research questions, purpose, and predictions

Two primary research questions guided the present investigation: First, is revision more effective than non-revision? Second, what revision method is best? To date, no study we are aware of has examined the revision process of note taking exclusively and systematically. The first question was addressed in Experiment 1. During a period between note taking and review, participants either revised their original lecture notes or recopied them. Recopying notes is a common practice for lecture note-taking students left to their own devices (Jairam and Kiewra 2010; Karpicke et al. 2009). The second question was addressed in Experiment 2. To determine the effect of pauses on revision, participants either revised lecture notes during pauses interspersed throughout the lecture or revised them during one equally timed pause at the end. To determine the effect of partners on revision, participants either revised notes alone or with a partner. This two-factor design produced four revision groups: pause/partner, pause/no partner, no pause/partner, and no pause/no partner. Dependent measures for both experiments included (a) notes that were examined for ideas noted originally and during revision and (b) achievement test scores measuring fact and relationship learning.

Three theoretical accounts guided our predictions. First, because revision might serve a retrieval function wherein originally noted ideas spur the recall of previously non-noted ideas, we predicted that the revision group would record more notes and achieve more than the recopy comparison group (revision effect). Second, because lecture pauses distribute learning, we predicted that groups with revision pauses interspersed throughout the lecture would record more notes and achieve more than those with one equally timed revision opportunity following the lecture (pause effect). Third, because working with a partner allows for note sharing and collaborative retrieval, we predicted that those revising with a partner would record more notes and achieve more than those revising alone (partner effect).

Experiment 1

Experiment 1 addressed the first research question, is revision effective, by comparing the performance of a revision group and non-revision (recopy) group.

Method

Participants and design

Participants were 59 undergraduate education majors enrolled in an educational psychology course at a large Midwestern university who participated in order to receive research participation credit. Fifty-four percent were female, most were juniors and seniors (85 %), and 88 % held grade-point averages (GPAs) of 3.0 or higher. Participants were assigned randomly to either the revision group ($n = 29$) or to the recopy (non-revision comparison) group ($n = 30$).

Materials

Materials included a demographic survey, a lecture, blank paper and pens for note taking and revision/recopy activities, a vocabulary filler task, and an achievement test. The demographic survey asked students to declare their gender (a. Male, b. Female), class standing (a. Freshman, b. Sophomore, c. Junior, d. Senior), approximate overall GPA (a. 3.5–4.0, b. 3.0–3.4, c. 2.5–2.9, d. 2.0–2.4, e., below 2.0), and prior knowledge about reinforcement schedules (a. Yes, b. No), which was the lecture topic. These demographics were collected because they are sometimes related to academic achievement and students' use of study strategies (e.g., DeBerard et al. 2004; Kiewra 1989b).

The 14-min, 1902-word lecture covered the topic of reinforcement schedules. This topic and amount of coverage were standard for the course in which participants were enrolled. Participants covered this topic later in the course weeks after the present study was conducted. The lecture was audio-recorded (for standardization between groups) and presented at a rate of 136 words per minute. An audio-recorded presentation mode was chosen (over video-recorded) because the lecture was exclusively verbal (spoken words with no written or graphic supplements), making any visual display unnecessary. The lecture introduced four types of schedules and then covered each in turn: fixed ratio, variable ratio, fixed interval, and variable interval. For each schedule, information was provided with regard to definition, example, behavior rate, and behavior pattern. The last lecture section covered extinction for fixed and variable schedules.

Blank paper was provided for participants to record lecture notes and to revise or recopy notes following the lecture. Participants were given black pens for recording lecture notes and given red pens for revising or recopying notes. Different colored pens were used so that original notes could be distinguished from revised or recopied notes for analysis.

The filler task was 10 vocabulary multiple-choice questions taken from sample Scholastic Aptitude Test items. For example: The revolution in art has not lost its steam, it ____________ on as fiercely as ever (a. trudges, b. meanders, c. edges, d. ambles, e. rages). This filler task was also used to determine if groups differed in verbal ability.

The 20-item multiple-choice achievement test measured fact and relationship learning. The 10-item fact portion was a measure of lower-level, rote learning. Each fact item covered one lecture fact. For example: (1) Which schedule yields a scallop response pattern (a. fixed interval, b. variable interval, c. fixed ratio, d. variable ratio)? (2) Which best defines how extinction occurs (a. reinforcement is no longer delivered, b. punishment is delivered rather than reinforcement, c. reinforcement is delivered in gradually smaller and smaller amounts, d. a person has to respond more and more to earn reinforcement)? The 10-item relationship portion was a measure of higher-level, associative learning. Each relationship item covered an implicit (unstated) relationship between two schedules. For example: (1) Which schedules involve slow responding (a. fixed, b. variable, c. ratio, d. interval)? (2) Which schedules involve rapid extinction (a. fixed, b. variable, c. ratio, d. interval)? A content expert reviewed the achievement test and confirmed content validity; each portion sampled the lecture content adequately and representatively (Haynes et al. 1995). Internal consistency, as measured by Cronbach's alpha, was .310 for the fact items and .718 for the relationship items. The low internal consistency coefficient for the fact items perhaps occurred because each item targeted a unique fact; the items, by nature, were not supposed to correlate with one another. In addition, low internal consistency could also be an artifact of the short test length (Onwuegbuzie and Daniel 2002). The internal consistency for the relationship items was acceptable (Frisbie 1988).

Procedure

Participants gathered in a single classroom and were assigned randomly to the revision or recopy group. Participants received a folder that contained common materials, general instructions, and group specific instructions. General instructions informed participants that they would record notes in their own style using a provided black ink pen while listening to a 14-min lecture and then study those notes for 10 min before completing an unrelated vocabulary task (5 min) and a lecture-related fact and relationship test (10 min). Group-specific instructions for the revision group informed them that they would have 15 min to revise lecture notes immediately following the lecture in order to make them more complete for review. They were told to use the provided red ink pen to add to their original notes anything that might have been missed during the lecture and anything else that could help them learn the material. Group specific instructions for the recopy group informed them to recopy their notes for 15 min following the lecture. After instructions were read, all participants completed the demographic survey and then proceeded through the lecture, revision/recopy, review, and testing phases as directed.

Scoring

Tests were multiple-choice and were, therefore, scored objectively based on scoring keys. All notes were scored for completeness using a scoring sheet that included all of the 95 lecture idea units derived from the lecture transcript. According to Kintsch's (1988) model of text comprehension, an idea unit (or proposition) is a conceptual unit composed of an argument and its relations. A sample idea unit in the present study was: a variable ratio schedule (argument) involves rapid responding (relation). One point was awarded for each idea unit recorded. Thus, the maximum score was 95 points. Two scores were derived: original notes, based on what was written in black ink during the lecture; and additional notes, based on what was recorded in red ink during the revision period. The first author scored all notes. A reliability check was conducted by having another trained rater independently score about one third of the notes. Peason's r inter-rater correlation coefficient was .89 for original notes and .73 for additional notes. These indices exceeded the threshold of good inter-rater reliability (Cohen 1988).

Results

Preliminary analyses were conducted on demographic variables (gender, class standing, GPA, and prior knowledge) and on verbal ability (vocabulary score) to ensure that the groups were comparable. Table 1 presents group statistics. Chi square tests assessed group

Table 1 Experiment 1 group statistics for demographic variables

	Revision ($n = 29$)		Recopy ($n = 30$)	
	n	M (%)	n	M (%)
Gender				
Male	14	48	13	43
Female	15	52	17	57
Class standing				
Freshman	0	0	1	3
Sophomore	4	14	4	13
Junior	1	3	5	17
Senior	24	83	20	67
Overall GPA				
3.5–4.0	14	48	12	40
3.0–3.4	13	45	13	43
2.5–2.9	2	7	5	17
2.0–2.4	0	0	0	0
Below 2.0	0	0	0	0
Prior knowledge				
Yes	8	28	9	30
No	21	72	21	70
Verbal ability	29	54	30	62

Table 2 Experiment 1 results summary of note and achievement measures by group

Variable	Revision ($n = 29$)		Recopy ($n = 30$)				95 % CI		Hedges' g
	M	SD	M	SD	t (57)	p	LL	UL	
Idea units in notes									
Original	38.6	10.5	38.0	9.2	.23	.82	−2.46	2.58	.06
Additional	3.2	2.3	0.0	0.0	7.57	.001	1.55	2.37	1.96
Achievement items									
Fact	45.9	18.6	43.3	15.8	.56	.58	−4.25	4.55	.15
Relationship	45.9	27.8	33.0	19.7	2.06	.04	−5.60	6.66	.53

Mean and standard deviation values are percentages

CI confidence interval, *LL* lower limit, *UL* upper limit

differences for categorical demographic variables (i.e., gender, class standing, GPA, and prior knowledge), whereas an independent t test assessed group difference for the continuous verbal ability variable. Results confirmed that the revision and recopy groups were comparable in terms of gender (χ^2 (1, $N = 59$) = .15, $p = .70$), class standing (χ^2 (3, $N = 59$) = 4.02, $p = .26$), GPA (χ^2 (2, $N = 59$) = 1.42, $p = .49$), prior knowledge (χ^2 (1, $N = 59$) = .042, $p = .84$), and verbal ability (t (57) = 1.71, $p = .09$).

Primary analyses pertained to the first research question: Is revision more effective than non-revision with respect to notes (original ideas and additional ideas) and achievement (fact and relationship test scores)? To answer this research question, independent t-tests[1] were employed to test differences between the revision and recopy groups on note measures and achievement measures. Independent t-tests were chosen over MANOVAs because t-test is the statistic of choice for two independent samples with small sample sizes (Larson and Farber 2011). Moreover, MANOVA increases the complexity and ambiguity of results and should, therefore, be avoided if possible (Tabachnick and Fidell 2007). When conducting t-tests, Bonferroni correction was used to control the family-wise error rate due to multiple comparisons (Rosenthal and Rubin 1984); therefore, the critical value for each individual test was .05/4 = .0125. In addition, Hedges' g was provided as a measure of effect size for each mean comparison (Lakens, 2013). According to Cohen (1992), effect sizes around .20 are considered small, around .50 are considered moderate, and around .80 are considered large. Table 2 provided the means, standard deviations, and other important test statistics.

Finally, correlational analyses were conducted to determine relationships between notes and achievement. If notes, and particularly additional notes, were related to achievement, then that would supply further evidence for the value of revision.

Notes

The first two rows of Table 2 contain group note-taking statistics. With respect to original notes, revision and recopy groups recorded comparable amounts during the lecture, $p = .82$. Incidentally, each group recorded about 38 % of lecture ideas, which is consistent with note completeness indices reported in previous studies (e.g., Kiewra 1985b; Titsworth

[1] The assumption of normality was checked for each dependent variable. Most had a normal distribution. Only one variable, additional notes, had a non-normal distribution. Therefore, both t test and Mann–Whitney U test were employed. The result of the Mann–Whitney U test mirrored the t-test result, so only t-test results were reported in line with other analyses.

Table 3 Experiment 1 correlations between note-taking indices and achievement measures

	Original notes	Additional notes	Fact items	Relationship items
Original notes	–	.146	.204	.309*
Additional notes		–	.310*	.494**
Fact items			–	.382*
Relationship items				–

* $p < .05$, ** $p < .01$

2004). With respect to additional notes, revisers naturally added more lecture ideas during the revision/recopy period than did re-copiers, $p < .001$.

Achievement

Group achievement statistics appear in the bottom section of Table 2. With respect to fact items, revisers and re-copiers performed comparably, $p = .58$. With respect to relationship items, there was a modest revision effect, $p = .04$. The effect was not statistically significant because the p value, .04, was greater than the adjusted alpha level, .0125. Group differences, however, are of practical importance given the mean differences ($M = 46$ % for revisers and $M = 33$ % for re-copiers) and moderate effect size.

Notes and achievement

Table 3 displays correlations between note-taking indices (original and additional) and achievement measures (fact and relationship). As can be seen, most correlations are statistically significant, and the largest correlations for fact and relationship achievement are with additional notes. These findings confirm previous research—that note taking is positively related to achievement (Peverly et al. 2003)—and offer new evidence that notes made during revision are especially related to achievement.

Discussion

The revision effect was upheld to some degree. Not surprisingly, the revision group, which was instructed to add additional notes following the lecture, did, in fact, add more notes than the non-revision comparison group, which was instructed to recopy their existing notes. With respect to achievement, the revision group scored higher on the relationship test than the non-revision group (although not statistically significant when a Bonferroni correction was used). In addition, notes made during revision were positively correlated with both fact and relationship achievement. We acknowledge, though, that revision had somewhat meager effects on note taking and achievement. Therefore, we followed up with Experiment 2 to seek ways to enhance revision through the use of lecture pauses and revision partners.

Experiment 2

Experiment 2 addressed the second research question, what method of revision is best, by investigating whether revision is best carried out (a) during lecture pauses or after the lecture and (b) with a partner or alone.

Method

Participants and design

Participants were 72 undergraduate education majors drawn from the same research pool as those in Experiment 1. Participants in this sample did not participate in Experiment 1. Seventy percent were female, most were juniors and seniors (90 %), and most (82 %) held GPAs of 3.0 or higher.

Participants were assigned randomly to one cell of a 2 × 2 factorial design that specified when and with whom lecture notes were revised. The first factor was when notes were revised: either during three 5-minute pauses spaced throughout the lecture or for 15 min following the lecture. The second factor was with whom notes were revised: either with a partner or alone. This research design resulted in a total of four groups: pause/partner ($n = 18$), pause/no partner ($n = 20$), no pause/partner ($n = 14$), and no pause/no partner ($n = 20$).

Materials

Materials were identical to those used in Experiment 1, except that there were two versions of the lecture. One ran from start to finish without interruption for the no-pause groups. The other version was divided into three roughly time-equivalent segments for the pause groups. Pauses came during natural breaks in the content. The first lecture pause came at about five minutes, the second at about ten minutes, and the last at the end of the 14-minute lecture.

Internal consistency, as measured by Cronbach's alpha, was .304 for the fact items on the achievement test and .620 for the relationship items. As with Experiment1, the relatively low internal consistency coefficient for the fact items perhaps occurred because each item targeted a unique fact; the items, by nature, were not supposed to correlate with one another. In addition, the short test length might have contributed to the low internal consistency coefficient. The internal consistency for the relationship items was acceptable.

Procedure

The four groups participated in the same classroom, with the same experimenter, but at different times. In this way, each group participated in a classroom-like setting with all its participants completing the same activities. Although this convenience sampling technique is a threat to internal validity, the experimenter reduced the threat by strictly following a script that ensured that all groups were treated equally except for their group-specific instructions and activities.

All participants completed the demographic survey and then received and followed experimental instructions. They were told that they would record notes in their own style using a provided black ink pen while listening to a 14-min lecture and then study those notes for 10 min before completing an unrelated vocabulary task (5 min) and a lecture-related fact and relationship test (10 min). All groups were also told they would have 15 min to revise lecture notes in order to make them more complete for review. Specifically, pause groups were told to revise during three 5-minute pauses spaced throughout the lecture. No-pause groups were told to revise one time for 15 min immediately following the lecture. Partner groups were told to revise with a partner (students numbered off before the lecture to determine partners). No-partner groups were told to revise alone. All groups were told to use the provided red ink pen to add to their original notes anything that might have been missed during the lecture and anything else that could help them learn the material.

Scoring

The scoring process for notes and test items was identical to that described in Experiment 1. With regard to notes, a reliability check was conducted by having another trained rater score independently about one third of the notes. Peason's r inter-rater correlation coefficient was .85 for original notes and .90 for additional notes. These indices exceeded the threshold of good inter-rater reliability (Cohen 1988).

In addition to these quantitative scoring procedures, notes made during revision were also examined qualitatively to investigate the nature of revised notes more fully. The original scoring method used in Experiment 1 simply determined how many new idea units were added to notes (note additions). This qualitative examination also assessed note extensions (additional information that makes an idea unit more complete) and note elaborations (additional information linking the noted idea to information outside the lecture) that were ignored in the original scoring method. For example, a student might have recorded this statement in original notes and been credited with one idea unit: "Extinction is difficult—slot machine." During revision, the student might have extended that note this way ("Extinction is difficult, for example, it would take a long time to figure out that a slot machine is not paying off") and/or added this elaboration ("Another example is ignoring a baby's crying during night") but not have received credit for adding new notes.

Results

Preliminary analyses were conducted on demographic variables (gender, class standing, GPA, and prior knowledge) and on verbal ability (vocabulary score) to ensure that the groups were comparable. Table 4 presents group statistics. Chi square tests assessed group differences for categorical demographic variables, and a one-way ANOVA assessed group differences for the continuous verbal ability variable. Results confirmed that the four groups were comparable in terms of gender (χ^2 (3, $N = 72$) = 2.65, $p = .45$), class standing (χ^2 (6, $N = 72$) = 4.62, $p = .59$), GPA (χ^2 (9, $N = 72$) = 8.15, $p = .52$), prior knowledge (χ^2 (3, $N = 72$) = 2.39, $p = .50$), and verbal ability (F (3, 68) = 1.15, $p = .34$).

Primary analyses pertained to the second research question: What manner of revision is best with respect to notes and achievement? Two sets of dependent variables, notes[2] and achievement, were analyzed separately using 2-way MANOVAs,[3] with pause and partner as independent variables. Both multivariate tests had statistically significant results. With respect to the two types of notes, there were a significant multivariate interaction effect of pause and partner, Wilks' lambda = .86, $p = .008$, and a main effect for pause, Wilks'

[2] The sample size for notes analyses was less than that for achievement because two sets of notes were misplaced and could not be scored.

[3] The assumption of normality was checked for each dependent variable. Most had a normal distribution, except additional notes. Therefore, in addition to the overall MANOVA test, a log transformation was performed on the additional-notes measure and a one-way ANOVA followed. The significant interaction effect between pause and partner was confirmed using the log transformation, just as in MANOVA. Therefore, only MANOVA results were reported.

Table 4 Experiment 2 group statistics for demographic variables

	Pause/no partner ($n = 20$)		Pause/partner ($n = 18$)		No pause/no partner ($n = 20$)		No pause/partner ($n = 14$)	
	n	*M(%)*	*n*	*M(%)*	*n*	*M(%)*	*n*	*M(%)*
Gender								
Male	6	30	3	17	6	30	6	43
Female	14	70	15	83	14	70	8	57
Class standing								
Freshman	0	0	0	0	0	0	0	0
Sophomore	4	20	1	5	1	5	1	7
Junior	7	35	7	39	11	55	6	43
Senior	9	45	10	56	8	40	7	50
Overall GPA								
3.5–4.0	13	65	9	50	7	35	6	43
3.0–3.4	4	20	5	28	10	50	5	36
2.5–2.9	3	15	3	17	3	15	3	21
2.0–2.4	0	0	1	5	0	0	0	0
Below 2.0	0	0	0	0	0	0	0	0
Prior knowledge								
Yes	9	45	5	28	7	35	3	21
No	11	55	13	72	13	65	11	79
Verbal ability	20	57	18	59	20	50	14	52

Table 5 Experiment 2 mean percentages (and standard deviations) among groups for idea units in notes and achievement items

Groups	Idea units in notes		Achievement items	
	Original *M* (SD)	Additional *M* (SD)	Fact *M* (SD)	Relationship *M* (SD)
Pause/no partner ($n = 20$)	49.3 (8.8)	4.7 (2.3)	50.5 (18.2)	55.5 (19.6)
Pause/partner ($n = 18$)	56.7 (10.4)	7.4 (4.4)	55.6 (17.9)	51.1 (19.1)
No pause/no partner ($n = 20$)	44.5 (9.1)	3.9 (2.9)	44.5 (15.7)	38.0 (23.5)
No pause/partner ($n = 14$)	46.8 (9.4)	2.2 (1.6)	42.9 (18.2)	31.4 (18.3)

The sample size for idea units in notes of no pause/partner group is 12: two sets of notes were misplaced and could not be scored

lambda = .688, $p < .001$; but the main effect for partner was not significant, $p = .088$. With respect to the two types of achievement, the multivariate interaction effect was not significant, $p = .717$, but there was a significant main effect for pause, Wilks' lambda = .821, $p = .001$. The main effect for partner was not significant, $p = .313$. All significant MANOVAs were followed up with univariate analyses for each dependent variable and then with tests of simple effects and main effects when appropriate. Effect sizes (i.e., eta squares) were also provided. According to Cohen (1992), effect sizes around .02 are small, around .13 are moderate, and around .26 are large. Table 5 presents interaction level results involving the individual groups (pause/no partner, pause/partner, no

Table 6 Experiment 2 mean percentages (and standard deviations) among combined groups for idea units in notes and achievement items

Groups	Idea units in notes		Achievement items	
	Original *M* (SD)	Additional *M* (SD)	Fact *M* (SD)	Relationship *M* (SD)
Pause ($n = 38$)	52.8 (10.2)	6.0 (3.7)	52.9 (18.0)	53.4 (19.2)
No pause ($n = 34$)	45.4 (9.1)	3.3 (2.6)	43.8 (16.5)	35.3 (21.5)
Partner ($n = 32$)	52.7 (11.0)	5.3 (4.4)	50.0 (18.8)	42.5 (21.0)
No partner ($n = 40$)	46.9 (9.2)	4.3 (2.6)	47.5 (17.1)	46.7 (23.1)
Total ($n = 72$)	49.4 (10.3)	4.7 (3.5)	48.6 (17.8)	44.9 (22.1)

For original notes and additional notes, the sample size of no pause groups was 32, the sample size of partner groups was 30, and the total sample size for note measures was 70

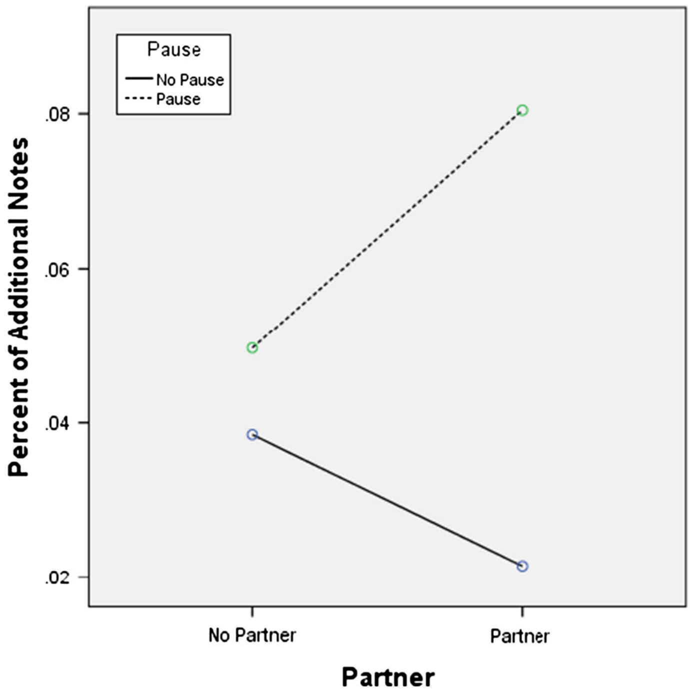


Fig. 1 Experiment 2 interaction effect of pause and partner on additional notes

pause/no partner, no pause/partner), and Table 6 presents main effect level results involving the combined groups (pause, no pause, partner, no partner). In each table, note-taking results appear on the left side, and achievement results appear on the right side.

Notes

With respect to original notes, there was no interaction effect, F (1, 66) = 1.24, $p = .27$, $\eta^2 = .002$. However, there were main effects for pause, F (1, 66) = 10.20, $p = .002$,

Table 7 Frequencies for each category of revised notes

Group	Note		
	Additions	Extensions	Elaborations
Pause/no partner	51	54	7
Pause/partner	76	34	11
No pause/no partner	40	66	9
No pause/partner	16	7	1
Total	183	161	28

$\eta^2 = .13$, and for partner, F (1, 66) = 4.33, $p = .04$, $\eta^2 = .06$. As shown in Table 6, pause groups (M = 52.8 %) recorded more original notes than no-pause groups (M = 45.4 %), and partner groups (M = 52.7 %) recorded more original notes than no-partner groups (M = 46.9 %).

With respect to additional notes, there was an interaction for pause and partner, F (1, 66) = 8.63, $p = .005$, $\eta^2 = .12$. Interaction results appear in Table 5 and are depicted in Fig. 1. The interaction can be interpreted two ways. First, we examine the simple effect of the pause variable at each level of the partner variable: When participants revised with partners, pause groups (M = 7.4 %) added about 5 % more notes than no-pause groups (M = 2.2 %), $p < .001$, 95 % CI [3 %, 7.5 %]; when participants revised alone, pause groups (M = 4.7 %) and no-pause groups (M = 3.9 %) added comparable amounts of notes, $p = .21$, 95 % CI [− 1.1 %, 2.8 %]. Second, we examine the simple effect of the partner variable at each level of the pause variable: When there were lecture pauses, revising with a partner (M = 7.4 %) yielded 2.7 % more additional notes than revising alone (M = 4.7 %), $p = .001$, 95 % CI [0.7 %, 4.7 %]; when there were no lecture pauses, revising with a partner (M = 2.2 %) or alone (M = 3.9 %) resulted in comparable additions to notes, $p = .10$, 95 % CI [− 0.5 %, 3.9 %].

With respect to the qualitative analysis of additional notes, findings are presented in Table 7. Inspection of Table 7 yields the following revision observations: (a) note extensions occurred about as often as note additions, (b) note extensions were somewhat more common among students revising alone than with a partner, and (c) note elaborations were rare.

Achievement

With respect to fact items, there was no pause-by-partner interaction effect, F (1, 68) = .65, $p = .42$, $\eta^2 = .01$. However, there was a main effect for pause, F (1, 68) = 5.1, $p = .03$, $\eta^2 = .07$. As shown in Table 6, pause groups (M = 52.9 %) scored 9 % higher on fact items than no-pause groups (M = 43.8 %). There was no main effect for partner, F (1, 68) = .17, $p = .68$, $\eta^2 = .002$. Although the pause-by-partner interaction was not statistically significant, there is a pattern in the Table 5 data of practical importance. It appears that the combination of pause and partners worked best for learning facts. Notice that partners scored about 12 % higher under pause conditions (M = 55.6 %) compared to no-pause conditions (M = 42.9 %). Such differences were not as evident for those revising alone. They scored just 6 % higher when working under pause conditions (M = 50.5 %) compared to no-pause conditions (M = 44.5 %).

With respect to relationship items, there was no interaction effect of pause and partner, F (1, 68) = .05, $p = .82$, $\eta^2 = .001$. However, there was a main effect for pause, F (1,

68) = 14.6, $p < .001$, $\eta^2 = .18$. As shown in Table 6, pause groups ($M = 53.4$ %) scored 18 % higher on relationship items than no-pause groups ($M = 35.3$ %). The main effect of partner, F (1, 68) = .13, $p = .26$, $\eta^2 = .002$, was not statistically significant.

Discussion

First, revising notes during lecture pauses uniformly aided note taking and achievement. Revising notes on three occasions during lecture pauses, versus once following the lecture, resulted in more original and additional notes, and in higher fact and relationship achievement. Second, revising notes with a partner, versus alone, aided note taking but not achievement. Revising with a partner resulted in more original notes but not in more additional notes or in higher achievement scores. Third, the interaction pattern for additional notes revealed that revision is best carried out during pauses and with partners. Revision during pauses with a partner produced more additional notes than revision without pauses and partners. The combined superiority of pauses and partners for notes, however, was not statistically significant for fact or relationship achievement (although partners scored 12 % higher under pause conditions than under no-pause conditions for fact items). Finally, the qualitative examination of additional notes during the revision period showed that revision was more than the addition of new ideas. It also involved substantial note extensions that helped bolster or clarify previously noted ideas. In some instances, revision also entailed elaboration, although such revision was relatively rare.

General discussion

The present study investigated revision, the missing link between note taking and the review of notes. We proposed that a note revision period after notes are recorded might yield more complete notes to review as students use noted ideas as retrieval cues to recall and note additional ideas absent from their original notes. We also proposed that revision might best be carried out during lecture pauses, instead of after the lecture, and with a partner, instead of alone, because lecture pauses might distribute learning and because partners might share and retrieve lecture ideas not previously noted by one partner or the other. Based on these beliefs, two primary research questions were posed and addressed. First, is revision more effective than non-revision? Second, what revision method is best?

Is revision effective?

The first primary research question was answered in Experiment 1 by comparing note-taking and achievement results of those who revised notes following a lecture with those who recopied notes. Results suggested a modest revision effect—revision is superior to no revision. In terms of notes, revisers naturally added more notes than non-revisers during the revision process, but just 3 % more. In terms of achievement, revisers outperformed non-revisers on relationship items, which were an index of associative learning—the ability to relate ideas that were presented independently. Revision might boost relationship performance for two reasons. First, revision increased the number of additional notes; it is well established that having more notes is associated with higher achievement (Peverly et al. 2003; Williams and Worth 2002). Second, revision perhaps had underlying cognitive benefits beyond simple note additions. The process of using original notes to retrieve additional lecture points might somehow encourage revisers to relate lecture ideas to one another. For example, revisers reading the noted idea, "variable schedules involve rapid responding," might have related this idea to "fixed schedules involve slow responding." In fact, there was modest evidence for elaborative revision in Experiment 2. This associative linking of ideas might occur because revision is an active process requiring learners to think about lecture ideas in meaningful ways. Meanwhile, we discount the possibility that revision helped simply because of additional exposure to lecture notes. The comparison group in Experiment 1 spent the same amount of time as revisers recopying their lecture notes, but such rote exposure did not boost notes or achievement.

What revision method is best?

The second primary research question was answered in Experiment 2 by examining the main and interaction effects of pauses and partners with respect to note taking and achievement.

Pause effect

The pause effect (revision pauses interspersed throughout the lecture are superior to one equally timed revision opportunity following the lecture) was upheld. Revision pauses led to increased original and additional notes and to higher fact and relationship achievement than revision without pauses. Pauses might be instrumental because they divide lectures into smaller units that make learning distributed rather than massed. Distributed learning, in turn, aids attention, encoding, and consolidation (Cepeda et al. 2006).

Pauses might aid attention because pauses break lectures into parts so that attention is better maintained throughout the lecture. Previous research has shown that with un-paused lectures, attention wanes and note taking decreases in latter stages (Scerbo et al. 1992).

Pauses might also aid encoding because learners tend to relate information stemming from multiple but similar contexts. This recent explanation for encoding advantages in distributed learning is called reminding theory (Benjamin and Tullis 2010). In the present study, the similarity among pause contexts (both in nature and in content) might have reminded learners to associate and encode lecture ideas across pauses. For example, Pause 2 material about variable ratio schedules might have reminded learners about Pause 1 material about fixed ratio schedules and prompted the joint encoding of the two concepts. Again, there was modest evidence in Experiment 2 that note revisions sometimes involved such elaboration. The encoding benefit of pauses might particularly explain why pauses had their largest effect on relationship learning, which depended on relating information spaced throughout the lecture.

Pauses might also aid memory consolidation—the stabilization of memory traces after initial acquisition (Wickelgren 1972). Distributed learning enhances memory consolidation in general and relational memory in particular because repeated exposure to information creates stronger and better organized synaptic connections among memory traces in the brain (Dash et al. 2004; Karpicke 2012). In the present study, improved consolidation, as the result of pauses, might have solidified memories but also given learners a progressively better framework for assimilating lecture ideas in notes from one lecture segment to the next.

Partner effect

The partner effect (revising with a partner is superior to revising alone) was upheld to some degree. Although those revising with partners and those revising alone did not differ in terms of fact or relationship achievement, there were note-taking differences between groups. Those with partners recorded more original notes, but not more additional notes. In terms of additional notes, the qualitative analysis in Experiment 2 revealed that those revising alone were actually somewhat more likely to extend originally noted ideas than were those revising with partners. In terms of original notes, it might seem surprising that those with partners recorded more, but perhaps students who knew they would be partnered were motivated to record complete notes to hold up their end of the note-revision partnership. Such social responsibility, or absence of social loafing (Brickner et al. 1986), is consistent with findings from social psychology (Gillies 2004) and from cooperative learning studies (Delgado-Tellez and Raposo 2011).

We thought that revising with a partner would especially produce more additional notes and higher achievement because revisers would not only get the benefit of their own notes acting as retrieval cues, they would also get access to their partner's original notes and their partner's retrieved notes. Such was not the case. According to the ICAP model (Chi and Wylie 2014), true interactive and constructive collaborations take place only if each partner "generates some knowledge beyond what was presented in the original learning materials" (p. 223). The qualitative examination of participants' added notes in Experiment 2, however, showed that the majority of additional notes were ideas from the lecture (note additions and note extensions), rather than new ideas (note elaborations). This new idea deficit might explain why the partner effect was not stronger. Moreover, working with a partner under experimental conditions might not be effective because (a) partnership skills take time to develop (Johnson and Johnson 1999), and (b) participants lacked motivation to engage in meaningful collaborations. Aitken and Hatt (2012) found that when students participated in collaborative note taking, it was beneficial when students had strong motivation to collaborate.

It seems that the potential partner effect was only observed to some degree when partners and pauses were combined. As shown in Table 5, the pause/partner group, relative to the no pause/partner group, recorded about 10 % more original notes, 5 % more additional notes, scored 13 % higher on fact items, and 20 % higher on relationship items. Moreover, the pause effect for fact learning was more than twice as large for partners than for no partners as seen in Table 5. Partners scored 5 % higher than those revising alone under pause conditions but scored less than 2 % higher under no-pause conditions. The combination of pauses and partners was perhaps somewhat effective because those in the pause/partner group were doubly aided. They reaped the benefits of both pauses (distributed learning) and partners (note sharing and collaborative retrieval). In summary, present results indicate that collaboration is not always effective. In a lecture setting, it works somewhat better for revising notes on multiple occasions throughout the lecture than just one time following the lecture.

Conclusions, limitations, and implications

In conclusion, the present study made new inroads into the scientific study of note taking. First, it conceptualized note taking as a three-step process of note taking, revision, and review. Second, it examined the independent effects of revision and found that revision is superior to no revision. Third, it examined how best to revise and found that revision is best when carried out during pauses and that the combination of pauses and partners has merit and holds promise. Fourth, it added revision as a new student-centered means to boost lecture note taking because students can, on their own, revise their notes before reviewing them. Revision can also be added to other instructor-centered means (presenting full notes, presenting skeletal notes, presenting cues, and re-presenting the lecture) for increasing note taking.

One limitation of the study was in how prior knowledge was assessed. A single self-report item measured participants' prior knowledge of the lesson topic. This self-report measure was crude because it did not directly assess prior knowledge but only participants' estimations. Future studies could use assessments that directly measure prior knowledge, such as a free recall test that asks participants to write down what they know about the topic (Dochy et al. 1999).

Another limitation was the low internal consistency of the fact achievement items. Although the low internal consistency coefficient was perhaps an artifact of short test length, it brought uncertainty to the reliability of the fact learning measure. Therefore, results for fact learning should be interpreted with caution.

Some educational implications follow from this study. First, students should revise lecture notes. Second, instructors should provide occasional lecture pauses for revision and possibly advocate that students work with partners during these pauses to make notes more complete. Third, instructors should warn students not to recopy notes because such rote rehearsal activity does not increase notes or boost achievement.

In terms of research implications, researchers might replicate the present study under more contemporary conditions involving computer-assisted instruction, computer note taking, or on-line partner consultation, especially in light of recent research comparing taking notes longhand versus taking them via computer (Bui et al. 2013; Mueller and Oppenheimer 2014). Perhaps revision, pause, and partner variables can aid note taking and achievement for computer-aided learning environments too. Existing programs are already in use for partnered note taking (e.g., Microsoft Office OneNote), but such programs are untested for revision. Researchers might also unpack the pause effect to determine if the distributed learning advantage of pauses is due to timeliness (revision occurs close in time to note taking) or amount (there is less information to process at one time). This issue might be investigated, as was done in the present study, by comparing the performance of those who revise during pauses spaced throughout the lecture with those who revise following the lecture, with one exception: Those revising after the lecture would also revise lecture notes in three five-minute intervals, with each interval focused on lecture notes corresponding to one of the three lecture segments. Researchers might also investigate whether partner familiarity or partner training aids partner interaction and improves revision, especially for partners working together one time following a lecture. Finally, researchers might seek ways to improve revision—perhaps through training—both in note quantity and elaborative quality.

References

Aharony, N. (2006). The use of deep and surface learning strategies among students learning English as a foreign language in an Internet environment. *British Journal of Educational Psychology, 76*, 851–866. doi:10.1348/000709905X79158.

Aiken, E. G., Thomas, G. S., & Shennum, W. A. (1975). Memory for a lecture: Effects of notes, lecture rate, and informational density. *Journal of Educational Psychology, 67*, 439–444. doi:10.1037/h0076613.

Aitken, A., & Hatt, G. (2012). Students taking notes and creating summaries together (or not). In A. Herrington, J. Schrape, & K. Singh (Eds.), *Engaging students with learning technologies* (pp. 147–165). Perth: Curtin University.

Armbruster, B. B. (2000). Taking notes from lectures. In R. F. Flippo & D. C. Caverly (Eds.), *Handbook of college reading and study strategy research* (pp. 175–200). Mahwah, NJ: Lawrence Erlbaum Associates.

Austin, J. L., Lee, M., & Carr, J. P. (2004). The effects of guided notes on undergraduate students' recording of lecture content. *Journal of Instructional Psychology, 31,* 314–320. Retrieved from: http://www.personal.psu.edu/ryt1/blogs/totos_tidbits/Effect%20of%20Guided%20Notes%20.pdf.

Barron, B. (2003). When smart groups fail. *Journal of the Learning Sciences, 12*, 307–359. doi:10.1207/S15327809JLS1203_1.

Bassili, J. N., & Joordens, S. (2008) Media player tool use, satisfaction with online lectures and examination performance. *International Journal of E-Learning & Distance Education, 22*, 93–108. Retrieved from: http://www.ijede.ca/index.php/jde/article/view/9/517.

Benjamin, A. S., & Tullis, J. (2010). What makes distributed practice effective? *Cognitive Psychology, 61*, 228–247. doi:10.1016/j.cogpsych.2010.05.004.

Bonner, J. M., & Holliday, W. G. (2006). How college science students engage in note-taking strategies. *Journal of Research in Science Teaching, 43*, 786–818. doi:10.1002/tea.20115.

Boyle, J. R. (2007). The process of note taking: Implications for students with mid disabilities. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 80*, 227–232. doi:10.3200/TCHS.80.5.227-232.

Brickner, M. A., Harkins, S. G., & Ostrom, T. M. (1986). Personal involvement: Thought provoking implications for social loafing. *Journal of Personality and Social Psychology, 51*, 763–769. doi:10.1037/0022-3514.51.4.763.

Brown, C. M. (1999). *Human-computer interface design guidelines*. Exeter: Intellect Books.

Bruffee, K. A. (1999). *Collaborative learning: Higher education, independence, and the authority of knowledge* (2nd ed.). Baltimore, MD: Johns Hopkins University Press.

Bui, D. C., & Myerson, J. (2014). The role of working memory abilities in lecture note-taking. *Learning and Individual Differences, 33*, 12–22. doi:10.1016/j.lindif.2014.05.002.

Bui, D. C., Myerson, J., & Hale, S. (2013). Note-taking with computers: Exploring alternative strategies for improved recall. *Journal of Educational Psychology, 105*, 299–309. doi:10.1037/a0030367.

Castello, M., & Monereo, C. (2005). Students' note-taking as a knowledge-construction tool. *Educational Studies in Language and Literature, 5*, 265–285. doi:10.1007/s10674-005-8557-4.

Cepeda, N. J., Pashler, H., Vul, E., Wixted, J. T., & Rohrer, D. (2006). Distributed practice in verbal recall tasks: A review and quantitative synthesis. *Psychological Bulletin, 132*, 354–380. doi:10.1037/0033-2909.132.3.354.

Chi, M. T. H., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist, 49*, 219–243. doi:10.1080/00461520.2014.965823.

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

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159. doi:10.1037/0033-2909.112.1.155.

Crooks, S. M., White, D. R., & Barnard, L. (2007). Factors influencing the effectiveness of note taking on computer-based graphic organizers. *Journal of Educational Computing Research, 37*, 369–391. doi:10.2190/EC.37.4.c.

Dash, P. K., Hebert, A. E., & Runyan, J. D. (2004). A unified theory for systems and cellular memory consolidation. *Brain Research Reviews, 45*, 30–37. doi:10.1016/j.brainresrev.2004.02.001.

DeBerard, M. S., Spielmans, G. I., & Julka, D. C. (2004). Predictors of academic achievement and retention among college freshmen: A longitudinal study. *College Student Journal, 38*, 66–80.

Delgado-Tellez, M., & Raposo, A. P. (2011, November). Motivating creativity and cooperation in classroom. In *Proceedings of the 4th international conference of education, research and innovation, Madrid, Spain* (pp. 1699–1703). Retrieved from http://library.iated.org/publications/ICERI2011.

Di Vesta, F. J., & Gray, S. G. (1972). Listening and note taking. *Journal of Educational Psychology, 63*, 8–14. doi:10.1037/h0032243.

Di Vesta, F. J., & Gray, S. G. (1973). Listening and note taking: II. Immediate and delayed recall as functions of variations in thematic continuity, note taking, and length of listening-review intervals. *Journal of Educational Psychology, 64*, 278–287. doi:10.1037/h0032243.

Dochy, F., Segers, M., & Buehl, M. M. (1999). The relation between assessment practices and outcomes of studies: The case of research on prior knowledge. *Review of Educational Research, 69*, 145–186. doi:10.3102/00346543069002145.

Ebbinghaus, H. (1964). *Memory: A contribution to experimental psychology* (H. A. Ruger, C. E. Bussenius, & E. R. Hilgard, Trans.). Mineola, NY: Dover Publications. (Original work published 1885).

Einstein, G. O., Morris, J., & Smith, S. (1985). Notetaking, individual differences, and memory for lecture information. *Journal of Educational Psychology, 77*, 522–532. doi:10.1037/0022-0663.77.5.522.

Exley, K., & Dennick, R. (2009). *Giving a lecture: From presenting to teaching* (2nd ed.). London: Routledge.

Frisbie, D. A. (1988). Reliability of scores from teacher-made tests. *Educational Measurement: Issues and Practice, 7*, 25–35. doi:10.1111/j.1745-3992.1988.tb00422.x.

Gillies, R. M. (2004). The effects of cooperative learning on junior high school students during small group learning. *Learning and Instruction, 14*, 197–213. doi:10.1016/S0959-4752(03)00068-9.

Grabe, M. (2005). Voluntary use of online lecture notes: Correlates of note use and note use as an alternative to class attendance. *Computers & Education, 44*, 409–421. doi:10.1016/j.compedu.2004.04.005.

Haynes, S. N., Richard, D. C. S., & Kubany, E. S. (1995). Content validity in psychological assessment: A functional approach to concepts and methods. *Psychological Assessment, 7*, 238–247. doi:10.1037/1040-3590.7.3.238.

Howe, M. J. A. (1970). Using students' notes to examine the role of the individual learner in acquiring meaningful subject matter. *Journal of Educational Research, 64*, 61–63. doi:10.1080/00220671.1970.10884094.

Jairam, D., & Kiewra, K. A. (2010). Helping students soar to success on computers: An investigation of the SOAR study method for computer-based learning. *Journal of Educational Psychology, 102*, 601–614. doi:10.1037/a0019137.

Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory into Practice, 38*, 67–73. doi:10.1080/00405849909543834.

Kam, M., Wang, J., Iles, A., Tse, E., Chiu, J., Glaser, D. et al. (2005). Livenotes: A system for cooperative and augmented note-taking in lectures. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 531–540). New York: ACM. doi:10.1145/1054972.1055046.

Karat, C. M., Halverson, C., Horn, D., & Karat, J. (1999). Patterns of entry and correction in large vocabulary continuous speech recognition systems. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 568–575). New York: ACM. doi:10.1145/302979.303160.

Karpicke, J. D. (2012). Retrieval-based learning: Active retrieval promotes meaningful learning. *Current Directions in Psychological Science, 21*, 157–163. doi:10.1177/0963721412443552.

Karpicke, J. D., Butler, A. C., & Roediger, H. L. (2009). Metacognitive strategies in student learning: Do students practice retrieval when they study on their own? *Memory, 17*, 471–479. doi:10.1080/09658210802647009.

Katayama, A. D., & Crooks, S. M. (2003). Online notes: Differential effects of studying complete or partial graphically organized notes. *Journal of Experimental Education, 71*, 293–312. doi:10.1080/00220970309602067.

Kiewra, K. A. (1985a). Investigating notetaking and review: A depth of processing alternative. *Educational Psychologist, 20*, 23–32. doi:10.1207/s15326985ep2001_4.

Kiewra, K. A. (1985b). Learning from a lecture: An investigation of notetaking, review, and attendance at a lecture. *Human Learning, 4*, 73–77.

Kiewra, K. A. (1989a). A review of note-taking: The encoding-storage paradigm and beyond. *Educational Psychology Review, 1*, 147–172. doi:10.1007/BF01326640.

Kiewra, K. A. (1989b). Cognitive aspects of autonomous note taking: Control processes, learning strategies, and prior knowledge. *Educational Psychologist, 23*, 39–56. doi:10.1207/s15326985ep2301_3.

Kiewra, K. A., Benton, S. L., Kim, S., Risch, N., & Christensen, M. (1995). Effects of note taking format and study technique on recall and relational performance. *Contemporary Educational Psychology, 20*, 172–187. doi:10.1006/ceps.1995.1011.

Kiewra, K. A., Mayer, R. E., Christensen, M., Kim, S. I., & Risch, N. (1991). Effects of repetition on recall and note-taking: Strategies for learning from lectures. *Journal of Educational Psychology, 83*, 120–123. doi:10.1037/0022-0663.83.1.120.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction–integration model. *Psychological Review, 95*, 163–182. doi:10.1037/0033-295X.95.2.163.

Kobayashi, K. (2006). Combined effects of note-taking/reviewing on learning and the enhancement through interventions: A meta-analytic review. *Educational Psychology, 26*, 459–477. doi:10.1080/01443410500342070.

Konrad, M., Joseph, L. M., & Eveleigh, E. (2009). A meta-analytic review of guided notes. *Education and Treatment of Children, 32*, 421–444. doi:10.1353/etc.0.0066.

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers in Psychology, 4*, 1–12. doi:10.3389/fpsyg.2013.00863.

Lambiotte, J. G., Skaggs, L. P., & Dansereau, D. F. (1993). Learning from lecture: Effects of knowledge maps and cooperative review strategies. *Applied Cognitive Psychology, 7*, 483–497. doi:10.1002/acp.2350070604.

Larson, R., & Farber, E. (2011). *Elementary statistics: Picturing the world* (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Maydosz, A., & Raver, S. A. (2010). Note taking and university students with learning difficulties: What supports are needed? *Journal of Diversity in Higher Education, 3*, 177–186. doi:10.1037/a0020297.

Mitnik, R., Recabarren, M., Nussbaum, M., & Soto, A. (2009). Collaborative robotic instruction: A graph teaching experience. *Computers & Education, 53*, 330–342. doi:10.1016/j.compedu.2009.02.010.

Mueller, P. A., & Oppenheimer, D. M. (2014). The pen is mightier than the keyboard: Advantages of longhand over laptop note taking. *Psychological Science,*. doi:10.1177/0956797614524581.

O'Donnell, A., & Dansereau, D. F. (1993). Learning from lectures: Effects of cooperative review. *Journal of Experimental Education, 61*, 116–125. doi:10.1080/00220973.1993.9943856.

Omoigui, N., He L., Gupta, A., Grudin, J., & Sanocki, E. (1999). Time-compression: Systems concerns, usage, and benefits. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 136–143). New York: ACM. doi:10.1145/302979.303017.

Onwuegbuzie, A. J., & Daniel, L. G. (2002). A framework for reporting and interpreting internal consistency reliability estimates. *Measurement and Evaluation in Counseling and Development, 35*, 89–103. Retrieved from Academic Search Premier Database.

Peverly, S. T., Brobst, K. E., Graham, M., & Shaw, R. (2003). College adults are not good at self-regulation: A study on the relationship of self-regulation, note taking, and test taking. *Journal of Educational Psychology, 95*, 335–346. doi:10.1037/0022-0663.95.2.335.

Peverly, S. T., Vekaria, P. C., Reddington, L. A., Sumowski, J. F., Johnson, K. R., & Ramsay, C. M. (2013). The relationship of handwriting speed, working memory, language comprehension and outlines to lecture note-taking and test-taking among college students. *Applied Cognitive Psychology, 27*, 115–126. doi:10.1002/acp.2881.

Piolat, A., Olive, T., & Kellogg, R. T. (2005). Cognitive effort during note taking. *Applied Cognitive Psychology, 19*, 291–312. doi:10.1002/acp.1086.

Raver, S. A., & Maydosz, A. S. (2010). Impact of the provision and timing of instructor-provided notes on university students' learning. *Active Learning in Higher Education, 11*, 189–200. doi:10.1177/1469787410379682.

Reimer, Y. J., Brimhall, E., Cao, C., & O'Reilly, K. (2009). Empirical user studies inform the design of an e-notetaking and information assimilation system for students in higher education. *Computers & Education, 52*, 893–913. doi:10.1016/j.compedu.2008.12.013.

Roediger, H. L. (2000). Why retrieval is the key process in understanding human memory. In E. Tulving (Ed.), *Memory, consciousness, and the brain: The Tallinn conference* (pp. 52–75). Philadelphia, PA: Psychology Press.

Rosenthal, R., & Rubin, D. B. (1984). Multiple contrasts and ordered Bonferroni procedures. *Journal of Educational Psychology, 76*, 1028–1034. doi:10.1037/0022-0663.76.6.1028.

Scerbo, M. W., Warm, J. S., Dember, W. N., & Grasha, A. F. (1992). The role of time and cuing in a college lecture. *Contemporary Educational Psychology, 17*, 312–328. doi:10.1016/0361-476X(92)90070-F.

Schoen, I. (2012). Effects of method and context of note-taking on memory: Handwriting versus typing in lecture and textbook-reading contexts. *Pitzer Senior Theses*. Paper 20. Retrieved from http://scholarship.claremont.edu/pitzer_theses/20.

Stefanou, C., Hoffman, L., & Vielee, N. (2008). Note-taking in the college classroom as evidence of generative learning. *Learning Environment Resources, 11*, 1–17. doi:10.1007/s10984-007-9033-0.

Stringfellow, J. L., & Miller, S. P. (2005). Enhancing student performance in secondary classrooms while providing access to the general education curriculum using lecture formats. *Teaching Exceptional Children Plus, 1*, 1–16.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). Boston, MA: Pearson.

Thomson, D. M., & Tulving, E. (1970). Associative encoding and retrieval: Weak and strong cues. *Journal of Experimental Psychology, 86*, 255–262. doi:10.1037/h0029997.

Thorndike, E. L. (1912). The curve of work. *Psychological Review, 19*, 165–194. doi:10.1037/h0073541.

Titsworth, B. S. (2004). Students' note taking: The effects of teacher immediacy and clarity. *Communication Education, 53*, 305–320. doi:10.1080/0363452032000305922.

Titsworth, B. S., & Kiewra, K. A. (2004). Spoken organizational lecture cues and student notetaking as facilitators of student learning. *Contemporary Educational Psychology, 29*, 447–461. doi:10.1016/j.cedpsych.2003.12.001.

Vygotsky, L. S. (1962). *Thought and language*. Cambridge, MA: MIT Press. (Original work published in 1934).

Watts, M., & Becker, W. E. (2008). A little more than chalk and talk: Results from a third national survey of teaching methods in undergraduate economics courses. *The Journal of Economic Education, 39*, 273–286. doi:10.3200/JECE.39.3.273-286.

Wickelgren, W. A. (1972). Trace resistance and the decay of long-term memory. *Journal of Mathematical Psychology, 9*, 418–455. doi:10.1016/0022-2496(72)90015-6.

Williams, R. L., & Eggert, A. C. (2002). Notetaking in college classes: Student patterns and instructional strategies. *Journal of General Education, 51*, 173–199. doi:10.1353/jge.2003.0006.

Williams, R. L., & Worth, S. L. (2002). Thinking skills and work habits: Contributors to course performance. *Journal of General Education, 51*, 200–227. doi:10.1353/jge.2003.0007.

Wong, L. (2014). *Essential study skills* (8th ed.). Stamford, CT: Cengage Learning.

Yetter, G., Gutkin, T., Saunders, A., Galloway, A., Sobansky, R., & Song, S. (2006). Individual practice for complex problem solving: A cautionary tale. *Journal of Experimental Education, 74*, 137–159. doi:10.3200/JEXE.74.2.137-160.