

RESEARCH ARTICLE

Assessing students' use of optional online lecture reviews

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Summary

Online practice quizzes can be used to supplement instruction in the classroom. Such quizzes can engage retrieval practice, thereby improving learning and retention. However, despite their potential benefits, recent work suggests that students typically underutilize online practice quizzes. This article reports an observational classroom study, in which students were provided optional online reviews throughout the semester. The reviews could be accessed in test format, in which students were given multiple-choice questions and provided correct answer feedback, or in read format in which students were given the same questions and were shown the correct answers. Students who used the test format performed better on exams than students who used the read format or did not use the reviews. Nevertheless, the massive majority of the online reviews (approximately 88%) were not completed, highlighting the tendency for students to underutilize optional online reviews.

KEYWORDS

classroom study, online technology in the classroom, optional online reviews, retrieval practice, students' study behavior

1 | INTRODUCTION

Over the past decade, instructors have come to rely on the use of online learning tools to supplement classroom instruction. Indeed, it is fairly common for instructors to post course content and other learning exercises on course websites. Many of these tools can be used to implement various psychological learning principles. For example, the use of online practice quizzes can afford retrieval practice, in which retrieving information from long-term memory improves learning and retention of that information (Brame & Biel, 2015; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Roediger & Butler, 2011; Rowland, 2014).

However, simply giving students access to these quizzes may be insufficient to improve learning, as students might not use them. Although research in the cognitive and learning sciences has provided insight into how learning can be improved (e.g., retrieval practice; Carpenter, Pashler, & Cepeda, 2009), the translation of these findings to the classroom has been somewhat underwhelming. One obstacle is that many of these findings run counter to students' intuitions about

learning (Bjork, Dunlosky, & Kornell, 2013). Thus, a critical step for improving the translation of learning principles to the classroom is to understand students' tendencies to use evidence-based techniques for improving learning.

Research suggests that retrieval practice is somewhat underutilized as a method of study, as students typically prefer rereading textbook chapters and lecture notes (Karpicke, Butler, & Roediger, 2009; Susser & McCabe, 2013). Other studies have shown that when students are given the opportunity to complete optional online practice quizzes, participation is often low. One study found that only 39% of first-year psychology students completed an optional practice midterm exam (Carrillo-de-la-Pena et al., 2009). Related work has shown that when optional practice exams were made available to students, only 46% of first-year dentistry students (Olson & McDonald, 2004) and 52% of first-year medical students (Kibble, 2007) made use of them. Another study found that when students were provided optional quizzes throughout the semester, only 20% of those quizzes were completed (Johnson, 2006). More recent work has found that only about half of the students in an introductory biology course completed the online practice quizzes that were made available (Carpenter et al., 2017).

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Although these findings provide some insight into whether and how often students engage in retrieval practice, this topic remains understudied. Furthermore, many studies often used a single optional quiz to assess students' use of supplementary study materials (e.g., Carrillo-de-la-Pena et al., 2009; Kibble, 2007; Olson & McDonald, 2004). A single quiz limits the opportunity to observe students' patterns over time regarding when and how they use the quizzes. It also limits students' opportunities to use retrieval practice on a more regular basis, which would presumably coincide with better learning. Students' use of more frequent (i.e., daily) practice quizzes has not been widely studied, so it is not clear how students would make use of such resources. On the one hand, daily practice quizzes might be desirable to students because each quiz has only a small amount of information to review. On the other hand, completing daily quizzes might require greater diligence than completing a single quiz, and thus students may actually be less likely to complete practice quizzes that are offered daily compared with just once before the exam. Currently, sufficient classroom data are lacking on students' use of optional online quizzes over time, when and how they make use of those quizzes, and how those utilization patterns coincide with learning in the course.

To these ends, we report an observational classroom study, in which introductory psychology students were given the option of using online lecture reviews after each class over the course of the semester. These reviews could be accessed in test format, where students answered questions over each lecture, or in read format, where students simply read the questions and answers together. Given students' tendencies to report rereading as a common study strategy (Karpicke et al., 2009; Susser & McCabe, 2013), giving students the option to engage in either retrieval or rereading of course information provides direct observational data on their tendencies to choose one or the other. Observing *when* students complete the reviews also provides important insights into their preferred timing for completing reviews. Although a relationship between self-reported procrastination and academic achievement has been observed (Kim & Seo, 2015), there is a dearth of objective data demonstrating when students choose to review course information.

We examined how the patterns in students' selection of the reviews coincided with their learning in the course, measured via exam scores. Effects on exam scores cannot be attributed solely to students' review patterns, as these data are correlational and could be influenced by the characteristics of the students themselves who choose a particular review method. Importantly, however, real classroom data on these questions are lacking and can provide a critical addition to the experimental literature on retrieval practice (Carrier & Pashler, 1992; Kang & Pashler, 2014; Roediger & Butler, 2011). As objective data are lacking on when students tend to complete optional reviews, we report these data as well, along with an exploratory analysis linking the timing of students' reviews with their exam scores. Although self-report data indicate that students who procrastinate achieve lower exam scores (Kim & Seo, 2015), the current study provides much-needed data on a more objective measurement of this relationship in a real course setting.

To explore the potential reasons behind students' use of the online reviews, students were given an end-of-semester survey, which queried their reasons for using—or *not* using—the reviews, along with the study strategies they engaged in while preparing for exams in the course. Together with the observational data, the survey data addressed the important question of *why* students used the reviews. The combined observational and self-report data thus provide new insights into students' study behaviors and highlight potential factors that might drive these behaviors.

2 | METHOD

2.1 | Students and course

Participants were 929 undergraduate students from three sections of an introductory psychology course at Iowa State University.¹ The course was taught over a 16-week semester by three instructors, each of whom taught the course over a 5-week period (with 1 week of classes recessed for fall break). Each 5-week period consisted of nine class meetings, with the 10th class meeting set aside for an exam. The instructor for a given 5-week period taught all of the classes for that period, but did not teach any classes for a different 5-week period. There were three exams in the course, each corresponding to the end of one of the 5-week periods. This study was reviewed and approved by Iowa State University's Institutional Review Board.

2.2 | Stimuli, design, and procedure

For each class meeting, a set of practice questions pertaining to the lecture content was created by the second author and the course instructors, and these questions were posted on the online course management system. Students could select which type of review format, if any, they used. The test format consisted of multiple choice questions with five response options. For each test item, after students entered a response they were shown the correct answer. In the read format, the same items were used, but the item was shown with the correct response in bold green font, as shown in Figure 1. The content for a given review corresponded to the material that was taught in that day's lecture. The number of questions in each review ranged between 4–10, and the number was based on the content that was covered in that day's lecture. The concepts in the material from the review questions were tested on the corresponding exam for that section, but the exams included novel questions and did not repeat any of the questions from the reviews.

On the first day of class, the instructor notified students that two online lecture reviews would be posted per week, one after each class. Students were also notified that completing the reviews was optional and that they would not be awarded any points or penalized for not completing them. Both review formats were made available,

¹Detailed demographics were not collected due to confidentiality restrictions.

Test Question:

Which part of a neuron is responsible for passing on the electrical signal that allows it to communicate with other neurons?

- a) Dendrite
- b) Synapse
- c) Axon
- d) Soma
- e) Sodium pump

Read Question:

Which part of a neuron is responsible for passing on the electrical signal that allows it to communicate with other neurons?

- a) Dendrite
- b) Synapse
- c) Axon (Correct Answer)
- d) Soma
- e) Sodium pump

FIGURE 1 Example of a test and read question from the online lecture reviews [Colour figure can be viewed at wileyonlinelibrary.com]

and the students were free to use them if they chose, without being encouraged to use one type over the other. Students accessed the online lecture reviews via the online course management system, which the students were already using to access course materials. A link on the homepage was created titled "Lecture Reviews." Clicking on this link opened a list of folders corresponding to each week of the semester (e.g., Week 1, Week 2, etc.). Clicking on one of the folders revealed a link to the date and topic of each class meeting (e.g., August 27: History and Overview). Clicking on the date and topic then revealed two links to the practice questions for that day, one in test format (where the link read "Answer questions and get feedback") and one in read format (where the link read "Read questions with answers provided").

Students could click either of these links to access either format of the review from the time the review was posted all the way through the remainder of the semester. Questions were posted in both formats for each day of class, resulting in nine sets of review questions for each 5-week instructional period. All reviews could be accessed in either format and there was no limit on the number of times that a review could be completed. We tracked which format of the reviews students completed, when they completed them, and how their completion of the reviews corresponded with their exam scores at the end of each 5-week period. We based our analysis only on reviews that were fully completed, as reviews that students simply accessed but did not complete were not included.

At the end of the semester, students were asked to complete an eight-item, multiple-choice online survey (shown in Table 1), which queried the students' reasons for using the online reviews, as well as their general study habits for the course. Students were given one point of extra credit for completing this survey.

3 | RESULTS

The results of primary interest included (a) the completion rate of the online reviews, including the proportion of students who completed the reviews and the average proportion of reviews completed per student, (b) the completion rate of the reviews according to format:

either Test, Read, or some mixture of both (Test/Read, reflecting at least one review completed through Test, and at least one review—either the same, or a different one—completed through Read), (c) exam scores as a function of the format of reviews completed, (d) exam scores as a function of the proportion of reviews completed, and (e) exam scores as a function of performance on the reviews. We also report an exploratory analysis in which we examined the time during which students completed the reviews and performance on exams. To ensure that the analyses across the semester were based on the same students and unaffected by attrition, all analyses are based on the 903 students who finished the course and completed all three exams. As each five-week period involved a different instructor (one factor that could possibly influence students' approaches to studying or using the reviews), we examined the data separately across each five-week period.

3.1 | Completion rate of the reviews

We tracked the number of reviews that students completed prior to each of the three exams. Exams were noncumulative, so only completion of the reviews that were relevant to each exam were tracked.² That is, completion of the reviews pertaining to the first 5-week period of the course was tracked up until the time that Exam 1 was completed; completion of the reviews pertaining to the second 5-week period (without reference to the first 5-week period) was then tracked up until the time that Exam 2 was completed, and completion of the reviews pertaining to the third 5-week period (without reference to the first and second 5-week periods) was then tracked up until the time that Exam 3 was completed.

Across the semester, approximately 55% of students completed at least one of the reviews, either in test or read format, prior to exams. Figure 2a shows the proportion of students who completed at least one of the reviews prior to each exam, and which format they used. Figure 2b shows the overall average proportion of the reviews

²All analyses pertaining to the proportion of reviews completed were almost identical to the parallel analyses on the number of reviews completed, so we restrict the reported results to the proportion of reviews completed.

TABLE 1 End-of-semester online survey and the percentage of students who selected each option

1. **When studying information for Psych 101, which of the following study strategies did you regularly use? (Check all that apply).**
 - a. Re-reading lecture notes (81.2%)
 - b. Re-reading the textbook chapters (34.5%)
 - c. Taking notes during lectures (75.2%)
 - d. Copying or re-writing notes (35%)
 - e. Highlighting or underlining material while reading (28.6%)
 - f. Taking notes over material in the textbook (31.6%)
 - g. Making an outline of the material (15.6%)
 - h. Making a diagram, chart, or picture of the material (08.3%)
 - i. Trying to recall material from lecture or the textbook (66.1%)
 - j. Trying to explain the material to someone else (36.5%)
2. **If you used the lecture review questions on blackboard, what was your primary reason for doing so? (Check only one).**
 - a. The lecture review questions helped me learn the information (24.2%)
 - b. The lecture review questions helped me figure out how well I knew the information (33.2%)
 - c. I enjoyed doing the lecture review questions (02.8%)
 - d. Not applicable—I did not use the lecture review questions (39.6%)
3. **If you used the lecture review questions on blackboard, which method did you prefer? (Check only one).**
 - a. Answer questions and get feedback (28.4%)
 - b. Read questions with answers provided (16.7%)
 - c. I have no preference either way (10.6%)
 - d. Not applicable—I did not use the lecture review questions (44%)
4. **If you did not use the lecture review questions on blackboard, what was your primary reason? (check only one).**
 - a. I did not know about them (11.9%)
 - b. I tried them, but they did not seem to help me (07.5%)
 - c. I was not interested in using the lecture review questions (07.9%)
 - d. I use other methods of studying and did not need to use the lecture review questions (17.4%)
 - e. Not applicable—I used the lecture review questions (54.9%)
5. **When you use practice questions to study, which of the following do you think is most true? (Check only one).**
 - a. Practice questions are useful for telling me what I do and do not know (34.5%)
 - b. Practice questions are useful because I learn more for those questions that I answered incorrectly (18.2%)
 - c. Practice questions are useful because I learn more for both questions that I answer correctly and incorrectly (39.6%)
 - d. Practice questions are good only if I get all the answers correct (01.8%)
 - e. I do not use practice questions to study (03.9%)
6. **Have you taken other college courses that provide practice questions? In which of the following ways have practice questions been used in the other courses you have taken? (Check all that apply).**
 - a. In-class “clicker” questions (63.9%)
 - b. Online quizzes (73.2%)
 - c. Online daily lecture reviews (16.9%)
 - d. Online discussion questions (19.4%)
 - e. In-class discussion questions (40%)
 - f. Practice exams (66.6%)
 - g. I have not seen practice questions used in the other courses I have taken (06.4%)
7. **Out of all the college classes you have taken (including Psych 101), what percentage of classes used some kind of practice questions, in one form or another? (Check only one).**
 - a. 0% (01.3%)
 - b. 0–25% (15.6%)
 - c. 25–50% (25.1%)
 - d. 50–75% (31.6%)
 - e. 75–100% (25.9%)
8. **When studying for exams, which of the following best describes when you do most of your studying? (check only one).**
 - a. Throughout the semester as I learn the information (08.1%)
 - b. More than a week before the exam (25.9%)
 - c. Less than a week before the exam (30.8%)
 - d. Within a few days of the exam (24.2%)
 - e. The day before the exam (09.2%)
 - f. On the day of the exam (01.5%)

Note: For each item, the percentage of students who selected each option is presented in parentheses next to the corresponding option.

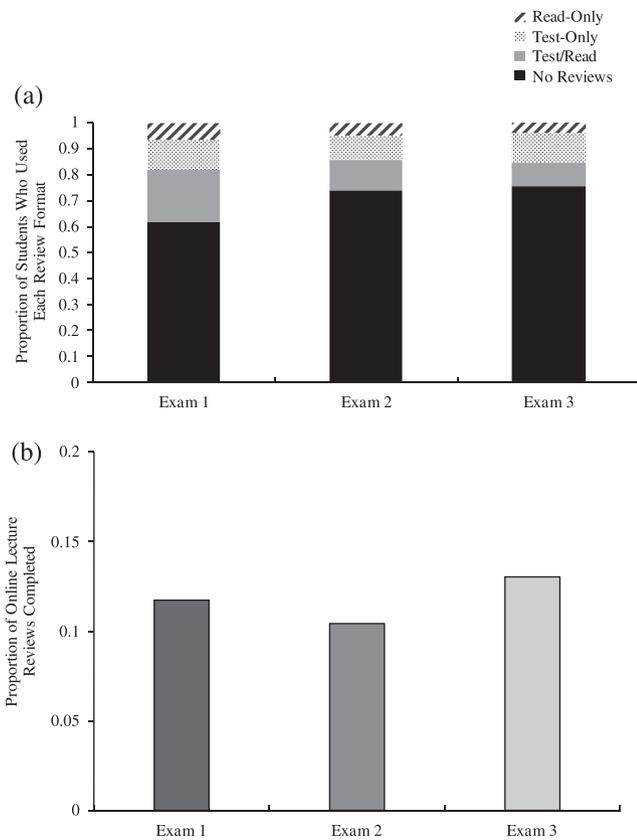


FIGURE 2 The proportion of students who used each review format prior to each exam (panel a), along with the average proportion of online reviews completed per student prior to each exam (panel b). In panel (a), students in the Test/Read group completed at least one review each via the test and read format; students in the Test-Only group completed at least one review using only the test format, and students in the Read-Only group completed at least one review using only the read format; students in the No Reviews group did not complete any of the online lecture reviews

that were completed per student (irrespective of review format) prior to each exam.

For Exam 1, approximately 38% of students completed at least one of the reviews (either in test or read format), and 14.5% of the reviews were completed. A chi-square test revealed differences in the proportion of students who used the various review formats, $\chi^2(3) = 697.65, p < .001$. Although the majority of students did not complete any of the reviews prior to Exam 1 (62% of students), among students who completed at least one review, the Test/Read format was most often used (19.9% of students), followed by Test-Only (11.9% of students), and then Read-Only (6.2% of students).

For Exam 2, approximately 26% of students completed at least one of the reviews, and 10.4% of the reviews were completed. There were again differences in the proportion of students who used each of the review formats, $\chi^2(3) = 1,171.15, p < .001$. Though most students did not complete any of the reviews (74.1% of students), among those who completed at least one review, the Test/Read format was

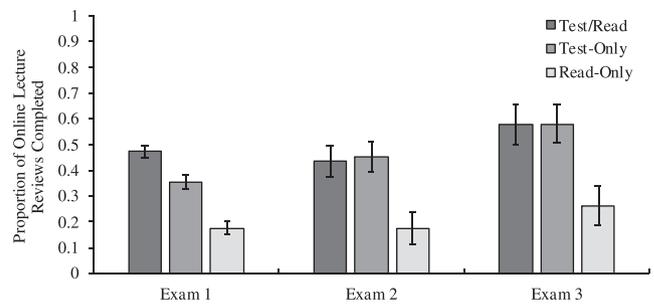


FIGURE 3 Proportion of online lecture reviews completed by students who used some mixture of the test and read formats (Test/Read), only the Test format (Test-Only), or only the read format (Read-Only) for Exams 1–3. Error bars represent standard errors of the mean

most often used (11.8% of students), followed by Test-Only (9.9% of students), and then Read-Only (4.3% of students).

For Exam 3, approximately 24% of students completed at least one of the reviews, and 13% of the reviews were completed. There were again differences in the proportion of students who used the different review formats, $\chi^2(3) = 1,241.31, p < .001$. Most students did not complete any of the reviews (approximately 76% of students), but among those who completed at least one review, the Test-Only format was most common (11.7% of students), followed by Test/Read (9% of students), and then Read-Only (3.8% of students).

Thus, across the three exams, the majority of students did not complete any of the reviews. When students did complete at least one review, however, they most often chose the Test/Read format or the Test-Only format, over the Read-Only format.

3.2 | Completion of reviews by format

We next examined the completion rate of the reviews according to which review format students used. Figure 3 shows the average proportion of reviews completed per student by format. This analysis is restricted to students who completed at least one review. These data were analyzed with one-way ANOVAs, and because we had no evidence-informed a priori predictions about the direction of these effects, all pairwise comparisons were examined with post hoc *t*-tests that used Bonferroni corrections for multiple comparisons ($\alpha = .016$).

For Exam 1, a one-way ANOVA revealed differences in the proportion of reviews completed based on format, $F(2, 339) = 18.52, p < .001, MSE = .107$. Students who used the Test/Read format completed a larger proportion of reviews ($M = .474, SE = .027$) than students who used Test-Only ($M = .355, SE = .027$), $t(284) = 2.79, p = .006, d = .331$, and Read-Only ($M = .176, SE = .027$), $t(233) = 6.06, p < .001, d = .79$. Students who used Test-Only also completed a larger proportion of reviews than students who used Read-Only, $t(161) = 3.70, p < .001, d = .583$.

For Exam 2, the same analysis revealed an overall effect of review format, $F(2, 230) = 10.85, p < .001, MSE = .108$, in that students who used the Test/Read format completed a larger proportion of reviews

($M = .436$, $SE = .061$) than students who used Read-Only ($M = .177$, $SE = .061$), $t(143) = 4.25$, $p < .001$, $d = .711$; students who used Test-Only ($M = .453$, $SE = .063$) also completed a larger proportion of reviews than students who used Read-Only, $t(125) = 4.40$, $p < .001$, $d = .787$. No difference emerged in the proportion of reviews completed between Test/Read and Test-Only, $p = .33$.

Finally, the same analysis for Exam 3 revealed an overall effect of review format, $F(2, 221) = 10.27$, $p < .001$, $MSE = .14$, in that students who used the Test/Read format completed a larger proportion of reviews ($M = .576$, $SE = .076$) than students who used Read-Only ($M = .261$, $SE = .076$), $t(113) = 4.14$, $p < .001$, $d = .779$; students who used Test-Only ($M = .579$, $SE = .074$) also completed a larger proportion of reviews than students who used Read-Only, $t(138) = 4.28$, $p < .001$, $d = .583$. No difference emerged in the proportion of reviews completed between Test/Read and Test-Only, $p = .964$.

Thus, across the three exams students who completed at least one review using the test format (either Test-Only or Test/Read) tended to complete a larger proportion of reviews than students who completed at least one review using only the read format. On average, these students completed close to 45% of the reviews prior to each exam (30.8% before Exam 1, 44.7% before Exam 2, and 57.8% before Exam 3). Students who relied on the read format, on the other hand, completed only 18% of the reviews before Exams 1 and 2, and only 26% of the reviews before Exam 3.

3.3 | Format of reviews and exam scores

We next explored students' average exam scores as a function of the format they chose to complete the reviews. Figure 4 shows the average proportion correct on each of the three exams according to the review formats that students used. These data were analyzed with one-way ANOVAs, and in this case uncorrected planned comparisons were conducted as follow-up tests.³

For Exam 1, the overall class average was .63 ($SE = .005$). A one-way ANOVA revealed differences in exam performance based on the review format that students used, $F(3, 899) = 4.43$, $p = .004$, $MSE = .021$. Students who used Test/Read ($M = .651$, $SE = .013$) outperformed students who did not complete any of the reviews ($M = .619$, $SE = .015$), $t(738) = 2.52$, $p = .012$, $d = .187$. Students who used Test-Only ($M = .665$, $SE = .015$) outperformed students who did not complete any of the reviews, $t(666) = 2.99$, $p = .003$, $d = .23$, as well as students who used Read-Only ($M = .617$, $SE = .024$), $t(161) = 2.00$, $p = .047$, $d = .315$. No other differences emerged.

For Exam 2, the overall class average was .744 ($SE = .004$). The same one-way ANOVA revealed an overall effect of review format, $F(3, 899) = 3.89$, $p = .009$, $MSE = .014$. Students who used Test/Read

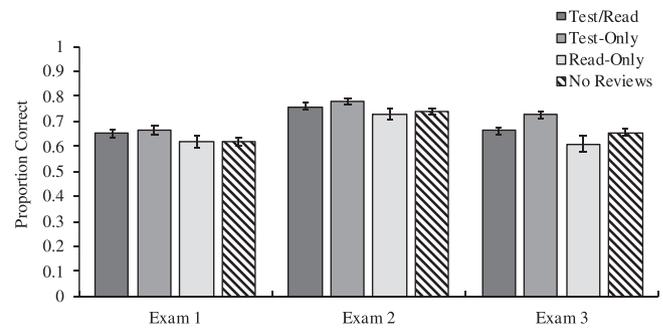


FIGURE 4 Proportion correct on exams and the standard error of the mean for students who used each online review format for Exams 1–3

($M = .759$, $SE = .012$) marginally outperformed students who did not complete any of the reviews ($M = .738$, $SE = .012$), $t(773) = 1.63$, $p = .099$, $d = .117$. Students who used Test-Only ($M = .78$, $SE = .013$) outperformed students who did not complete any of the reviews, $t(756) = 2.99$, $p = .003$, $d = .224$, and students who used Read-Only ($M = .727$, $SE = .023$), $t(126) = 2.26$, $p = .023$, $d = .403$. No other differences emerged.

For Exam 3, the overall class average was .665 ($SE = .005$). The same one-way ANOVA revealed a significant effect of review format, $F(3, 899) = 8.36$, $p < .001$, $MSE = .022$. Students who used Test-Only ($M = .727$, $SE = .015$) outperformed students who used Test/Read ($M = .662$, $SE = .015$), $t(185) = 2.91$, $p = .003$, $d = .428$, Read-Only ($M = .61$, $SE = .029$), $t(138) = 4.03$, $p < .001$, $d = .686$, and students who did not complete any of the reviews ($M = .656$, $SE = .015$), $t(786) = 4.60$, $p < .001$, $d = .328$. Additionally, students who used Test/Read marginally outperformed those who used Read-Only, $t(113) = 1.77$, $p = .062$, $d = .333$, and students who did not complete any of the reviews, $t(714) = 1.85$, $p = .047$, $d = .138$. No other differences emerged.

3.4 | Proportion of reviews and exam scores

Our next question was whether students who completed a greater proportion of reviews scored higher on exams, and whether this depended on the format of the reviews they completed. These analyses were restricted to students who completed at least one review.

For Exam 1, the proportion of reviews completed was positively related to exam scores ($r(340) = .254$, $p < .001$). A more detailed analysis revealed that this relationship was significant for students who used the Test-Only, $r(105) = .364$, $p = .001$, and Test/Read ($r(177) = .207$, $p = .005$), formats, but not for students who used the Read-Only format ($r(54) = .151$, $p = .27$).

The same results were found for Exam 2, where the overall proportion of reviews completed was again positively related to exam scores ($r(232) = .264$, $p < .001$), and this result occurred for students who used the Test-Only ($r(87) = .33$, $p = .002$) and Test/Read ($r(104) = .192$, $p = .049$) formats, but not for students who used the Read-Only format ($p = .96$). Finally, the proportion of reviews completed was positively

³This test is fairly liberal, as it can increase the chance of a Type 1 error. However, this test was selected over more conservative ones (e.g., Bonferroni) because (a) all of the comparisons were planned, based on extensive evidence on the benefits of retrieval practice (e.g., Kornell & Vaughn, 2017) and thus we were more concerned about a Type 2 error than a Type 1 error, and (b) these analyses were run across three exams which provides the opportunity for replication, reducing the chances for a false positive result.

related to Exam 3 scores as well ($r(219) = .331, p < .001$), and this result occurred for students who used the Test-Only ($r(104) = .381, p < .001$) and Test/Read ($r(79) = .354, p = .001$) formats. For those who used the Read-Only format, the proportion of reviews completed was actually negatively associated with Exam 3 performance ($r(32) = -.377, p = .028$).

Thus, across the three exams, performance increased as students completed more online reviews prior to the exams. However, this relationship was only observed when students completed the reviews in test format (or a combination of test and read). When students completed the reviews in read format, either no relation or a negative relation was observed between the proportion of reviews completed and corresponding exam scores.

3.5 | Mediation analysis

The previous analyses indicate that (a) students completed a greater proportion of reviews via Test-Only compared to Read-Only, (b) exam

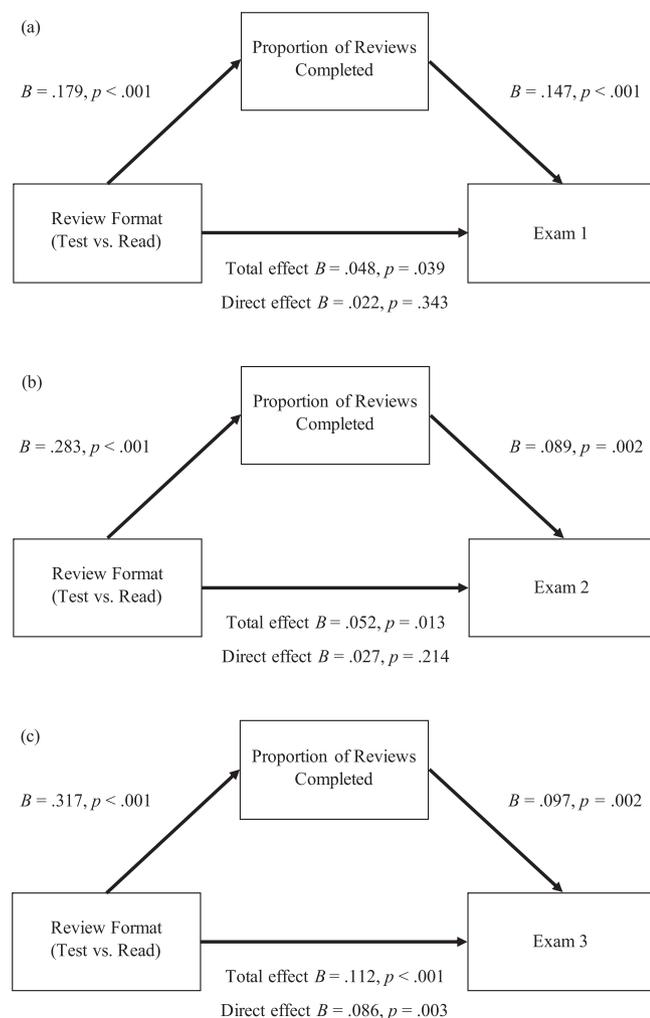


FIGURE 5 Mediation analysis of relationship between review format and exam scores mediated by proportion of reviews completed for Exam 1 (panel a), Exam 2 (panel b), and Exam 3 (panel c). All coefficients are unstandardized

scores were higher for students who used Test-Only compared to Read-Only, and (c) the proportion of reviews completed positively predicted exam scores. We therefore conducted a mediation analysis to determine whether the difference in exam scores between students in these groups was mediated by the proportion of reviews completed. To avoid potential complicating effects of mixing the test and read formats, students who used the Test/Read format were not included in these analyses.

Figure 5 shows the results of a bootstrapping analysis based on 5,000 samples. There was an overall effect of review format on exam scores, as exam scores were higher for the Test-Only group than the Read-Only group. This effect was mediated, however, by the proportion of reviews completed. The effect was fully mediated for Exam 1, $B = .026$, 95% CI [.011, .046], and Exam 2, $B = .025$, 95% CI [.009, .046], and partially mediated for Exam 3, $B = .031$, 95% CI [.009, .060]. Thus, students in the Test-Only group completed a greater proportion of reviews than students in the Read-Only group, and this greater proportion of reviews in turn predicted higher scores on the exams.

3.6 | Performance on the online reviews and exams

Next, we examine how performance on the reviews was related to performance on the exams. A multiple regression was conducted in which performance on the reviews and number of reviews completed were used as predictors of exam performance; this second predictor was included to control for total number of reviews that were completed. To further control for review type and proportion of reviews completed, these analyses were restricted to students in the Test-Only condition and only included students who completed all reviews for a given section; because students were shown the correct answers after responding, to avoid ceiling effects on the reviews, only the score on the first attempt for each review was included in the analyses. Performance on the reviews positively predicted performance on Exam 1, $\beta = .786, F(1, 11) = 11.83, p = .006, MSE = .017$, Exam 2, $\beta = .621, F(1, 15) = 7.95, p = .013, MSE = .001$, and Exam 3, $\beta = .642, F(1, 38) = 19.15, p < .001, MSE = .004$, such that students who performed better on the reviews also performed better on the exams. Thus, students' knowledge of the online review material seems to be a reliable indicator of how well students will perform on the exams.

3.7 | Timing of the reviews and exam scores

Finally, we explored students' performance on exams as a function of when they completed the reviews. We took the timestamp of when each review was completed and computed the number of hours between completion of that review and the start of the corresponding exam. For each student, these data points were averaged together for each review completed, producing an average of how long before the

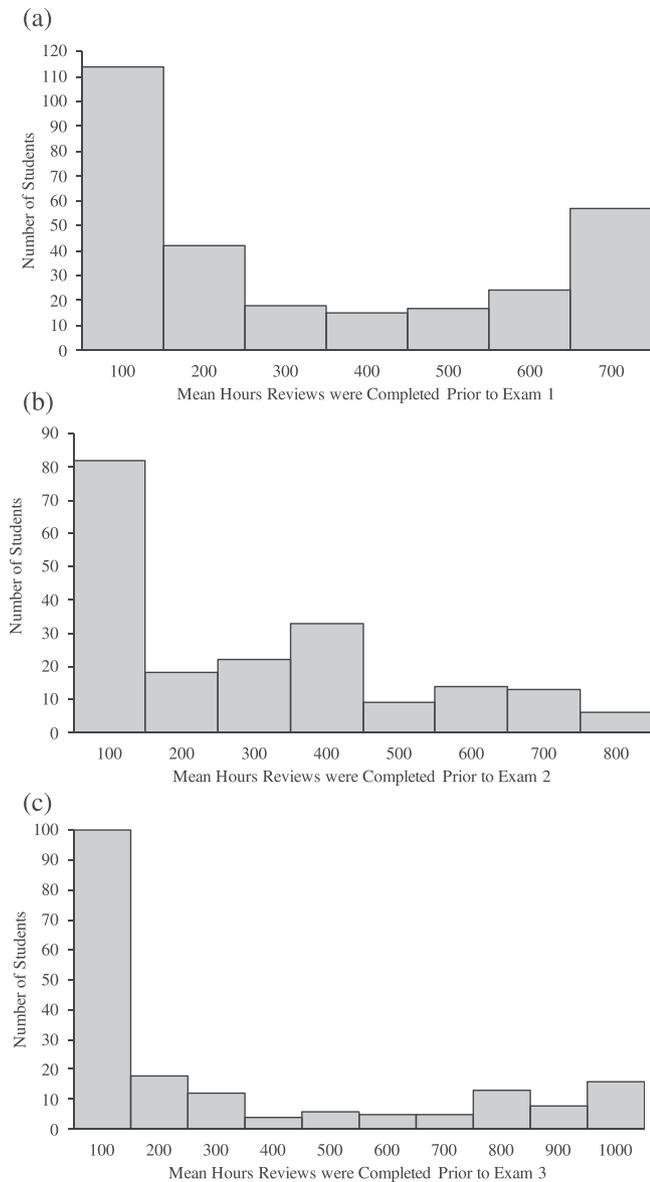


FIGURE 6 Frequency distribution of the mean number of hours before exams that students completed the online lecture reviews for Exam 1 (panel a), Exam 2 (panel b), and Exam 3 (panel c)

exam each student completed each of the reviews. Higher values on this measure indicate that students completed the reviews earlier (i.e., procrastinated less), whereas lower values indicate that students waited longer to complete these reviews (i.e., procrastinated more). In cases where a student completed the same review more than once, the timestamp of the earliest review was used.

Figure 6 shows the frequency distribution of the mean hours prior to each exam that students completed the reviews (restricted to students who completed at least one of these reviews for each exam). As illustrated in Figure 6, students tended to complete the reviews closer to the exam, rather than far in advance. Students' mean completion times of the reviews prior to each exam were 61.7 h for Exam 1 (close to 33 days after the first review was made available), 95.5 h for Exam 2 (close to 31 days after the first review was made available),

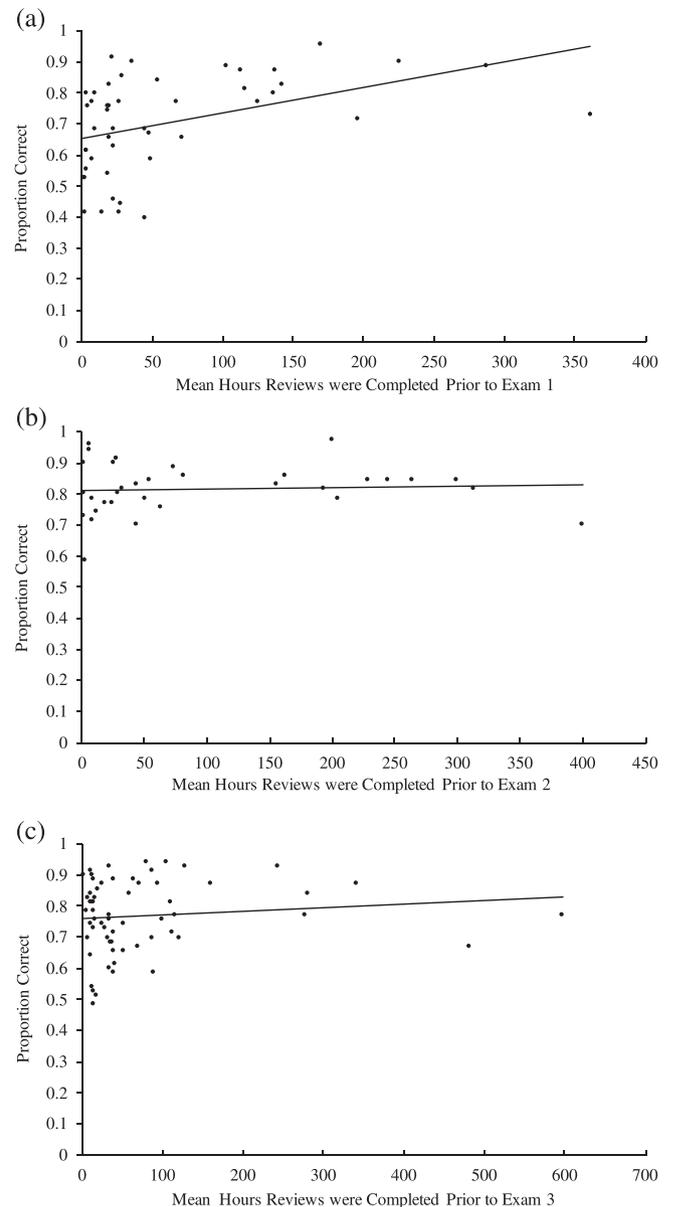


FIGURE 7 Relations between the average number of hours the online lecture reviews were completed before each exam and the corresponding exam score. Panels (a)–(c) correspond to Exams 1–3, respectively

and 76.8 h for Exam 3 (close to 32 days after the first review was made available). Thus, on average students were completing the reviews about 2 to 4 days prior to exams (approximately 31–33 days after the first review was made available). Students' average completion times for the reviews ranged from 19 min before the exam to 978 h (approximately 6 weeks) before the exam.⁴

We next explored whether the timing of the reviews predicted exam performance. This analysis was restricted to students who completed all of the reviews for the corresponding exam, leaving 48 students for Exam 1 (Test/Read $N = 33$, Test-Only $N = 14$, Read-Only, $N = 1$), 35 students for Exam 2 (Test/Read $N = 17$, Test-Only $N = 18$; no students from the Read-Only group met the inclusion criteria), and

62 students for Exam 3 (Test/Read $N = 21$, Test-Only $N = 41$; no students from the Read-Only group met the inclusion criterion). This criterion was used because for students who missed any of the reviews; it cannot be determined whether or not they would have procrastinated.⁴

Figure 7 shows the relation between procrastination and performance on each exam. As explained above, each student in Figure 7 completed all of the available reviews. Some students completed at least one of these reviews more than once, however, leading to differences in the number of exposures to each review. To control for exposure differences, the relation between timing of the reviews and subsequent exam scores was examined using a multiple regression model consisting of both timing of reviews and overall number of reviews as predictors.

Across all three exams, there was a positive relation between review completion time and subsequent exam scores. For Exam 1, students who procrastinated less performed better than students who procrastinated more, $\beta = .436$, $t(45) = 3.25$, $p = .002$. Although there was a slight trend in the same direction, procrastination did not reliably predict performance on Exam 2, $p = .46$. On Exam 3, however, students who procrastinated less once again performed better than students who procrastinated more, although this effect was marginal, $\beta = .263$, $t(59) = 1.94$, $p = .057$. Although there are some inconsistencies in the statistical significance of the outcomes across the three exams, these exploratory analyses provide suggestive evidence that students who waited longer to complete reviews performed lower on exams.

3.8 | Survey results

We next report the results of the end-of-semester survey. A total of 60% of students completed the survey (544 students out of 903), reflecting a response rate that exceeds the recommended criterion for a class of over 900 students (see Nulty, 2008).

The survey results are shown in Table 1. When reporting their study strategies (Item #1), the most popular strategies were rereading lecture notes (81.2% of students) and taking notes during lecture (75.2% of students). Attempting to recall material from the lecture or textbook was also used but less often (66.1% of students). About one-third of students reported rereading textbook chapters (34.5% of students), taking notes over textbook material (31.6% of students), copying or re-writing notes (35% of students), and trying to explain the material to someone else (36.5% of students).

When asked why they used the online reviews (Item # 2), the most popular reason given was that the reviews allowed students to

figure out how well they knew the material (33.2% of students). Perhaps due to the tendency to use the reviews as a knowledge check, the type of review that students preferred most (Item # 3) was the test version (28.4% compared with 16.7% who preferred the read version). The most commonly reported reason for not using the reviews (Item # 4) was a preference for other study methods and the feeling that the reviews were not necessary (17.4% of students).

Students' beliefs about the effectiveness of practice questions (Item #5) paralleled their preference to use them as a knowledge check, as the most popular responses were that practice questions are helpful for telling students what they do and do not know (34.5% of students) and that they learn from both questions they answer correctly and incorrectly (39.6% of students). As far as students' experience with practice questions (Item # 6), a fairly large percentage indicated that their courses offer online quizzes (73.2% of students). However, only a few students (only 16.9%) reported having online daily lecture reviews, indicating that the online reviews employed as part of this study do not appear to be widely used.

Finally, in indicating when they do their studying (Item # 8), the most popular response was less than a week before the exam (30.8% of students). Very few students reported distributing their studying throughout the semester (8.1% of students), but also very few reported engaging in heavy cramming the day before (9.2% of students) or the day of the exam (1.5% of students).

4 | DISCUSSION

We report an observational classroom study, wherein students were provided optional online reviews throughout the semester. Although completing a greater proportion of these reviews was related to better exam performance, our findings show that 45% of students did not complete any online reviews, and only 12% of the total reviews were completed. These results are in line with previous findings, which have shown that students tend to underutilize optional online study quizzes and reviews (Carpenter et al., 2017; Carrillo-de-la-Peña et al., 2009; Johnson, 2006; Kibble, 2007; Olson & McDonald, 2004).

4.1 | Completion rate of online reviews

One question to consider is why the completion rates for the online reviews were so low. When students were asked why they did not use these reviews, the survey data indicate that the majority of students knew about the reviews, thus lack of knowledge is unlikely the reason. Instead, approximately 33% of students reported not using the reviews because they either used different methods to study, were not interested in the reviews, or did not find them useful. The reason completion rates were low might have therefore been due to a lack of interest or need for the online reviews, or skepticism in their utility.

⁴This procrastination measure is highly sensitive to the number of reviews completed, with lower numbers of reviews likely to overestimate or underestimate procrastination (depending on whether students did a single review, for example, right before the exam or far in advance). Restricting the analysis to students who completed all of the reviews ensures that students reviewed the same content and controls for the potential biasing effects of missed reviews.

In the present study, students who did not access the online reviews performed lower on the exams than students who used the test format of the reviews, pointing to the possibility that students who do not use the online reviews rely on sub-optimal study methods. Recent work has shown that simply making students aware of this difference in exam performance might be sufficient to increase students' use of online reviews (Carpenter et al., 2017). Specifically, Carpenter et al. reported a classroom study in which students' scores over the first two exams were partitioned, based on the type of online review method that students used (Test/Read, Test-Only, Read-Only, and no reviews). Students who used the Test/Read and the Test-Only review formats outperformed students who did not use the online lecture reviews and those who used the Read-Only format. After the second exam, all students were presented a lecture about how well students in each group performed on the first two exams. Following this presentation, students' use of the test format of the online reviews increased on the subsequent two exams, which coincided with an increase in performance on Exams 3 and 4. Thus, simply making students aware of how well their peers perform based on their method of review might motivate students to adopt more optimal study strategies.

4.2 | Procrastination

Although the online reviews were made available to students shortly after each lecture, most students who completed the reviews appeared to do so a few days prior to the exam. This finding suggests that many students may have engaged in the suboptimal practice of cramming most of their studying into a few days. These observational data confirm those of a recent survey study showing that students self-report doing most of their studying within a few days before the exam (Blasiman, Dunlosky, & Rawson, 2017; see also Geller et al., 2018). Previous research has shown that spacing study over several sessions often leads to better learning and retention than when studying is massed into fewer sessions (formally known as the *spacing effect*, or the *distributed practice effect*; Carpenter, 2017; Dempster, 1988). In line with this phenomenon, students who waited longer to complete the reviews achieved lower performance in two out of the three exams, despite completing all of the reviews. This effect was statistically reliable in Exam 1 and marginally reliable in Exam 3. Students' procrastination might account for the reason that the massive majority of the online reviews were not completed, as students might simply not have had enough time to complete them. Indeed, approximately 66% of students reported waiting until within a week of the exam to do their studying. Thus, one potential avenue of research that might increase students' use of online reviews is to examine how to reduce procrastination.

4.3 | Retrieval practice

Students who used the Test-Only format performed better on the exams than students who used the Read-Only format, as well students

who did not complete the online reviews. These results are in line with the vast literature on retrieval practice (Carpenter et al., 2009; Kornell & Vaughn, 2017), showing that retrieval enhances subsequent learning more so than restudy. Whereas the majority of studies on retrieval practice are laboratory-based, the current study provides a real classroom demonstration that students who review information via testing with feedback score higher on subsequent exams than students who review the same information via reading the questions and answers. Furthermore, in the present study, the questions on the online reviews were always different (but covered the same topics) from the questions that appeared on exams, and thus suggest that the benefits of retrieval during study do indeed transfer to novel but related content.

For all three exams, students in the Test/Read and Test-Only groups completed a greater proportion of the reviews than students in the Read-Only group, and our mediation analysis showed that the advantage of Test reviews over Read reviews was mediated by the greater proportion of reviews completed via Test compared to Read. In accordance with these findings, the majority of students who reported using the online reviews indicated that they preferred the testing format. These findings suggest that students not only prefer test-based reviews, but also complete more of them compared to read-based reviews. This greater amount of practice might be an important contributor to the benefits of test-based learning in the classroom.

4.4 | Beliefs and study strategies

Research on students' self-reported use of retrieval practice shows that students tend to have some awareness of the metacognitive benefits of testing—often using self-testing to gauge their understanding of concepts (Geller et al., 2018; Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007). In line with this idea, the massive majority of students who reported using the online reviews indicated doing so because the reviews either helped them learn the material or highlighted the material they did not know. A similar pattern emerged when students were asked why they believed practice questions were useful, as the most popular responses were that practice questions help students either learn the material or help them figure out the material they do and do not know. In line with students' intuitions, our data show that students who performed better on the online reviews also performed better on the exams, suggesting that performance on these reviews might indeed provide students an accurate assessment of how well they know the course content.

With regard to general study strategies, students reported regularly engaging in various study activities that appear to rely on retrieval practice, such as explaining the material to another person (over 36% of students) and recalling material from the textbook or lecture (approximately 66% of students). Nevertheless, the most popular method of study was taking notes (75% of students) and rereading them (81% of students). Thus, although strategies that invoke retrieval practice appear to be common among students, rereading material remains a prevalent method of study.

4.5 | Limitations and future directions

Although the present findings are encouraging of the benefits of retrieval practice, they should be interpreted cautiously, as this was not a true experiment. Thus, we cannot be certain whether the differences in exam scores were due to the review format that students used or to differences among students. It is possible that using the test format leads to better learning. However, it is important to note that there were large differences in the number of students who chose to complete the different review formats, and because students self-selected into these groups, it is possible that differences in the number of students across these groups may reflect differences in group characteristics that may have contributed to the outcomes in unknown ways. One possibility is that better students are more likely to use the test format of the reviews and to perform better on the exams.

5 | CONCLUSION

The current study contributes much-needed data on students' voluntary use of optional online reviews. Though more than half of the students completed at least one review over the course of the semester, only 12% of the total reviews were completed. When students did complete the reviews, they performed highest on exams when they completed the reviews sooner rather than later, and when they completed the reviews in test format. These results parallel the beneficial effects of testing and spacing often found in the literature. However, the vast majority of the reviews were not completed, and among those that were, most were completed within a few days of the exams. Thus, when reviews are optional, students tend to complete them inconsistently and at suboptimal times. These results highlight the need for instructional methods that can counteract students' natural tendencies to avoid or delay reviewing course material.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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