

Quasi-Experimental and Experimental Assessment of Electronic Textbook Experiences: Student Perceptions and Test Performance

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An increasing number of psychology students encounter electronic textbooks (e-texts), whether by personal choice or instructor adoption. Across two studies—one quasi-experimental and one experimental—we compared students' experiences with print books versus e-texts. Study 1 capitalized on a naturally occurring comparison: the same course was taught across consecutive semesters at the same university using the same text, but once requiring a print book and once requiring an e-text. An anonymous survey revealed comparable ratings of the degree to which students across the two semesters felt their text was interesting, clear, able to hold their attention, and good value for their money. E-text students reported spending significantly more time on mid/end-of-chapter practice multiple-choice questions than did print book students, and enthusiasm for using an e-text was greater after experience with the modality. Study 2 was a controlled experiment in which participants read the identical section of a psychology text, but were randomly assigned to one of three conditions: (a) print book, (b) on-screen portable document format (PDF), or (c) interactive e-text. Once again, self-report measures were comparable across groups, with the exceptions being that interactive e-text participants reported spending the most time on practice multiple-choice questions and finding those questions most helpful. On a postreading test, interactive e-text participants outperformed other groups on items that were similar to the earlier practice questions, but the three groups did not differ significantly on overall test performance, providing no evidence that on-screen text presentation impaired memory or comprehension. Classroom implications, study limitations, and future research directions are explored.

Keywords: textbook, electronic media, technology, assessment, reading comprehension

While many psychology instructors find themselves pondering the potential advantages and disadvantages of adopting an electronic textbook (e-text) in their classes, one development in contemporary higher education is unambiguous: the e-text is here to stay. According

to a 2012 survey, 42% of college students reported having used an e-text at least once—a rate that rose to 60% in 2014 and 66% in 2016 (deNoyelles & Raible, 2017). Reduced production and distribution costs for publishers, the increasing availability of online open educa-

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tional resources, and a society-wide embrace of digital content suggest that this upward trajectory will only continue. This conclusion underscores the importance of assessing students' e-text experiences, an objective we pursue presently across two studies.

Many of the factors an instructor might consider in weighing e-text adoption are practical ones. Arguments in favor of e-texts include lower student costs, a shorter (or even continuous) text revision cycle, improved accessibility for students with learning disabilities or cognitive impairments, and eliminating the environmental costs of printing and shipping physical books. The focus of the present investigation, though, is assessing how electronic texts compare with print textbooks when it comes to undergraduate psychology students' perceptions and learning outcomes. In particular, how do students feel about using e-texts (and do their perceptions evolve along with experience with the modality)? Does student test performance vary after reading an electronic versus print textbook?

How Do Students Feel About E-Texts?

Multiple studies have indicated that while modern students are increasingly familiar with a range of electronic media, they continue to express preference for traditional, print textbooks (Buzzetto-More, Guy, & Elobaid, 2007; Daniel & Woody, 2013). Such preference has been observed behaviorally, as demonstrated in one study that tracked introductory psychology students who were allowed to choose between a print and electronic version of their assigned textbook (Shepperd, Grace, & Koch, 2008). Although the electronic text was the less expensive option, 90% of students opted for the print version.

Research like this, in which students' actual purchasing preferences are assessed, also provides an opportunity to compare the characteristics of readers who opt for electronic versus print texts. For example, Woody, Daniel, and Baker (2010) asked college students about a previous instance in which they had been presented with this same choice: print or e-text. The researchers found that participants' reports of how often they read text on their computer predicted their decision to use an e-text, but the following variables did not: gender, self-

reported comfort level with computers, and hours of computer use per week. Consistent with other self-report findings, students who chose the print version indicated greater satisfaction with their textbook than students who opted for the e-text (Woody et al., 2010).

It is worth noting, though, that many of the findings cited above are close to one decade old, and technologies—not to mention people's technological comfort levels and predilections—evolve rapidly. Indeed, in the Shepperd et al. (2008) study, the e-text option was a compact disc, a technology that few college students would encounter today. And in describing the nature of electronic texts, Woody et al. (2010) wrote: "Many e-textbooks are often a pdf of the actual textbook page" (p. 945). While this assessment would have been accurate when written, today's e-texts are much more likely to be heavy on interactive features and embedded videos, hosted on a proprietary software platform, and even accessible via mobile app.

Moreover, studies that compare students who have opted for a print book with those who have opted for an e-text do not speak directly to one question on the minds of many an instructor—namely, "If I adopt a required electronic version of a text in my class, how will my students react?" That students who choose an e-text might vary on some characteristics and outcomes from those who choose print is interesting, but just as important may be the reactions to an e-text of those students who never would have chosen such a modality on their own, but are assigned to use one in class.

Accordingly, one primary objective of the present investigation was to assess whether the conclusion that students prefer print textbooks continues to hold with an increasingly tech-savvy student body and amid rapid developments in the nature of e-texts themselves. To ask this question, we conducted a quasi-experimental investigation (Study 1), in which we compared the self-reported perceptions and experiences of two consecutive semesters of students in an undergraduate psychology course. In both semesters, students read the same text, but an e-text was required in one and a print copy in the other. We assessed satisfaction with their text, as well as any differences in how students used their e-text versus print book.

Does Student Test Performance Vary After Reading a Print Book Versus an E-Text?

A critically important question is how students learn when reading e-texts. Researchers have assessed this question via experimental design, randomly assigning participants to read a passage in either print or electronic format before taking a test on the material. Several such studies have found no significant difference by text modality, with comparable test scores in print and on-screen conditions (e.g., Grimshaw, Dungworth, McKnight, & Morris, 2007; Margolin, Driscoll, Toland, & Kegler, 2013; Rockinson-Szapkiw, Courduff, Carter, & Bennett, 2013; Wright, Fugett, & Caputa, 2013). For example, in one study, third and fourth graders in France were given 5 min to read a passage about the bloodstream (Porion, Aparicio, Megalakaki, Robert, & Baccino, 2016), either in print format or on a computer screen. They then took a written test on the passage, which included questions gauging surface-level recognition, semantic comprehension, and inferential ability. No performance differences emerged across text modality condition.

Other research has found evidence of decrements in test performance after reading material in electronic versus print form (e.g., Ackerman & Goldsmith, 2011; Singer & Alexander, 2017a; Wästlund, Reinikka, Norlander, & Archer, 2005). For example, Mangen, Walgermo, and Brønnick (2013) divided 72 high school students in Norway into two groups. Each group read the same passage of approximately 1,500 words, either in print format or on a screen as a static portable document format (PDF). Students subsequently completed a comprehension test, during which the original reading was still available to them (i.e., an “open-book” test). Results indicated superior test performance in the print versus electronic condition (Mangen et al., 2013).

Based in large part on findings such as these, popular science articles have advanced the argument that—increasing adoption rates aside—the use of electronic texts in college classrooms can impair student learning (e.g., Jabr, 2013; Wallis, 2013). Proposed mechanisms for such negative effects include that on-screen presentation disrupts the visual processing associated with reading on paper, is less effective at elic-

iting sustained reader attention, and prevents adaptive reading strategies such as highlighting and annotating (for reviews, see Ross, Pechenkina, Aeschliman, & Chase, 2017; Singer & Alexander, 2017b). It is important to note, however, that some studies have reported positive effects for learning outcomes via on-screen text (e.g., Meyer & Poon, 1997; Moore, & Zabucky, 1995).

Moreover, a close examination of the extant research reveals a range of important differences between the tasks often presented to research participants and the experiences of actual students. For example, although there are advantages in laboratory studies to using brief stimulus passages—including participant engagement and limiting the amount of scrolling required—college assignments require reading more than several hundred words at a time. Additionally, whereas lab studies often operationalize learning outcomes via measures of pure recall or remember/know assessments (where readers have to state whether or not they have a distinct episodic memory of learning particular material), college testing frequently requires students to draw inferences and assess higher-order conclusions. Furthermore, as noted above, the static PDF presentation of on-screen text used in most previous studies does not capture the more interactive experience of many of today’s e-texts.

As such, a second central objective of our investigation was to examine the influence of text modality on student learning outcomes via an experimental design that more closely approximates the contemporary undergraduate experience. We randomly assigned students to read from a chapter of a psychology text in one of three formats: print book, static PDF, or interactive e-text. Participants then completed a college-level multiple-choice test. The use of an interactive e-text enabled us to better approximate the type of digital technology that is increasingly used in today’s college courses, and inclusion of a PDF condition allowed for the potential disentangling of screen effects by specific type of electronic presentation. For example, consider a pattern whereby test performance was strongest in the e-text condition, followed by the print book condition, and followed by the PDF condition—this would suggest that the potential for negative screen effects is greatest for material presented in static form.

Summary

In many respects, higher education is just beginning its digital revolution, rendering essential the effort to keep up to date our understanding of how student feel about, interact with, and learn from electronic textbooks. With the rapid pace of technological advances, it is necessary to regularly reexamine empirical questions that were asked only a few years ago. In the present two studies, we attempted to follow up and extend previous research on e-text use through both quasi-experimental and experimental designs. In particular, we aimed to assess whether previous findings regarding (a) student preference for print books over e-texts, and (b) differences between learning outcomes for print and e-texts would emerge in a contemporary sample using interactive e-text technology. First, we assessed the perceptions and self-reported tendencies of undergraduates required to use an e-text in their psychology course. Second, we randomly assigned students to read a section of a psychology textbook in one of three different modalities to assess potential effects on reading and learning outcomes.

Study 1

Method

Participants. At the end of a fall semester of an undergraduate social psychology course (taught by one of the present authors) in which an interactive e-text had been required, we sent an online survey to all 101 registered students, 42 of whom responded. The following spring semester, a different instructor (not an author of this paper) used the same text but in print version. At the end of this semester, we sent a similar questionnaire to this new group of 62 students, 39 of whom responded. These sample sizes yielded a sensitivity to detect two-group effects of .63 or higher with 80% power (for between-groups comparisons), and to detect a paired-effect size within the e-text condition of .44 at 80% power (for the within-group comparison), indicating an 80% chance of revealing medium-sized effects (Cohen, 1988). We did not collect demographic data from the respondents, but the undergraduate student body at this small, private Research I university is predom-

inantly White (57%), female (51%), and between the ages of 18–22. Enrollment in this particular course across these two semesters was majority female (63%) and majority first-year/sophomore students (65%).

Materials. The course textbook was Aronson, Wilson, Akert, and Sommers (2015). Whereas the written content of the print book and e-text was identical, the e-text included interactive features: clickable links for citations that led to the full bibliography; interactive figures and tables; a chapter-opening polling question about students' own lives that provided real-time data from other readers; embedded videos, including reenactments of classic studies; shared writing prompts; and end-of-section/chapter practice multiple-choice questions that provided immediate feedback (and a hint after an incorrect response; these same practice questions appeared in the print text along with an answer key, but without feedback or hints). The list price for a new copy of the print text was more than twice that of 1-year of access to the interactive e-text, according to popular consumer websites.

Our survey focused on students' reading tendencies and their perceptions of the text. One question each asked respondents to use a scale of 1 (*not at all*) to 7 (*very much*) to rate how interesting the text was, how clearly it explained concepts, how well it held their attention, its value for what they paid for it, the regularity with which they answered the practice questions found at the end of each section and chapter, and their enthusiasm for using an interactive e-text in the future. In addition, those students who had used an e-text rated retrospectively how enthusiastic they had been about their text at the start of the semester. Students also estimated how many minutes they spent reading each assigned chapter.

Procedure. After the completion of all assignments (but before the calculation and release of final semester grades), an e-mail was sent to all students in each course asking for their voluntary participation in a brief survey about the assigned text. No incentives were offered for participation, and students were assured that responses (and even whether or not they had responded at all) would remain anonymous.

Results

Independent-samples *t* tests compared responses of the print text sample with those of the e-text sample.¹ As summarized in Table 1, for most measures, students' responses did not vary across type of text, $ps > .18$. Two notable exceptions emerged. First, students who had used an e-text reported having more regularly taken the end-of-section/chapter practice questions ($M = 5.63$) than did students who had used a print text ($M = 4.59$), $t(75) = 2.26$, $p = .03$, $d = .52$. Second, students who had used an e-text reported more enthusiasm about using an e-text in the future ($M = 4.65$) than did students who had used a print text ($M = 3.67$), $t(74) = 2.04$, $p = .05$, $d = .47$. Consistent with this finding, the e-text students also reported that their future enthusiasm ($M = 4.65$) was significantly greater—via paired-sample *t* test—than their recollection of how enthusiastic they had been about using an e-text at the start of the semester ($M = 3.14$), $t(36) = 5.55$, $p < .001$, $d = .97$.

Discussion

Study 1 capitalized on a naturally occurring comparison between two psychology courses using the same text, one requiring a print textbook and the other an interactive e-text. Results indicated that students offered similar assessments of their texts across modality. We found no evidence of the preference for print books reported by some previous studies, as students offered comparable ratings for how interesting, clear, and attention-holding the text was across the print and e-text semesters. Somewhat surprisingly, we also found no differences in the two samples' perceptions of the economic value of the text across semesters, despite the fact that the print textbook was considerably more expensive than was e-text access. Of course, it is possible that many students in the print condition bought less expensive used copies of the text or rented their book, thereby avoiding paying the list price.

One significant difference that emerged was that students using an e-text were more likely to report spending time on the mid/end-of-chapter multiple-choice questions. While some e-texts allow instructors to require completion of such questions for a grade, this was not so in the

course we assessed. Rather, students in the e-text condition chose to devote more time and effort to these optional questions, arguably a positive instructional development, given the benefits bestowed upon students by practice testing (Karpicke & Aue, 2015; Karpicke & Roediger, 2007). As described above, the interactive e-text allowed students to click to respond to each question and receive immediate feedback, including a hint if their initial response was incorrect. Perhaps the easy point-and-click nature of answering questions and receiving feedback in this format accounts for e-text students reporting a greater likelihood of answering these practice questions compared with students for whom the practice questions only appeared on a static page (with answer key printed in their book).

We also found evidence consistent with the conclusion that exposure to an e-text brings with it increased student enthusiasm for the modality. Students in the present sample who used an e-text were more enthusiastic about future e-text use than those who had not done so (and, indeed, more enthusiastic than they themselves recall having been at the start of the semester, though we acknowledge that the retrospective nature of this measure renders it susceptible to bias). This seems a noteworthy finding for instructors considering a switch to e-texts but concerned about student apprehension.

We did not, in the present study, attempt to link textbook modality to course outcomes such as final grades. Indeed, such an analysis would not have been meaningful; students across the two semesters used the same text, but they had different instructors, exams, and assignments. We did investigate time spent per chapter, finding a trend for students to report spending a bit longer to complete the same reading when using the e-text, but this difference was not statistically significant ($p = .18$). Finally, we note

¹ The quasi-experimental nature of these comparisons and the lack of random assignment to condition rendered it important to test for equality of variance; no evidence emerged that there were meaningful differences in variance across samples, and indeed, the *t* tests reported above produced similar results when equal variance was not assumed. The variability in degrees of freedom reported reflect missing data for some measures when participants left the item in question blank.

Table 1
Self-Report Textbook Ratings Across Print and E-Text Semesters in Study 1

Measure	Print text semester	E-text semester
How interesting was text?	5.64 (.90)	5.55 (1.23)
How clear was text?	6.05 (.89)	5.86 (1.28)
How well did text hold attention?	4.87 (1.28)	4.69 (1.68)
Text's value for money paid?	4.95 (1.43)	4.86 (1.52)
How regularly did you complete multiple-choice questions?	4.59 _a (2.12)	5.63 _a (1.91)
Enthusiasm for using interactive e-text in future?	3.67 _b (2.22)	4.65 _{bc} (1.98)
Enthusiasm for e-text when it was initially assigned	N/A	3.14 _c (1.30)
Minutes spent reading per chapter	69.33 (41.53)	83.63 (52.98)

Note. Standard deviations in parentheses. Means sharing a subscript differ significantly via *t* test at $p \leq .05$. All items other than minutes spent reading per chapter assessed on scale of 1 (*not at all*) to 7 (*very much*). N/A = not applicable.

once more that while this study compared two semesters of the same course at the same institution using the same text, a variety of factors remained outside of our control, including the student composition of the two courses, specifics related to the two instructors, and the assignments upon which final grades were based each semester. Moreover, many students opted not to respond to the course survey at all, raising the possibility of self-selection bias, though we also note that response rates were not drastically different across the two semesters sampled.

Study 2

In Study 2 we added to our investigation of students' e-text perceptions an experimental assessment of how the modality of an assigned reading affects test performance. As reviewed earlier, previous findings have been mixed on how print versus electronic presentation of text influences reading and learning outcomes, with some conclusions referencing disadvantages for digital content. We sought to examine this question using a contemporary college sample, a reading from an actual college text, a college-level test on the material, and a design that differentiated between a static PDF and interactive e-text presentation of the sort used today in many courses—steps intended to enable us to better understand student experiences with e-texts in actual classes. Our focus, therefore, was on differences in student outcomes when reading electronic versus print texts, but also on the specific effects of the interactive nature of the modern e-text compared with static, noninteractive digital text.

Method

Participants. We recruited 160 introductory psychology students to participate in exchange for course credit. Participants were randomly assigned to one of three conditions: print book ($n = 54$), PDF ($n = 54$), interactive e-text ($n = 52$).² These sample sizes were determined via power analysis, and yielded a sensitivity to detect two-group effects of .55 or higher with 80% power, indicating an 80% chance of revealing medium-sized effects (Cohen, 1988). This sample was drawn from the same university as in Study 1; in the introductory psychology pool (from which these participants were drawn), 57% of students were female and 78% were in their first year of college.

Materials. The stimulus reading was a ~3,900-word excerpt from the group processes chapter of the Aronson et al. (2015) social psychology textbook, specifically chosen because it was a topic that none of the students in the participant pool would learn or read about in their introductory course. The passage consisted of text, a table, two figures, and five optional end-of-section practice multiple-choice questions.

In the print book condition, this reading came in the form of a traditional hardcover textbook. In the PDF condition, a digital file with the same written and visual information with the

² One participant in the PDF condition was observed using the search function on the reading during the completion of the survey and what was supposed to be a closed-book test. Exclusion of data from this individual left the sample of 160 participants described here.

same pagination as the print book was presented on a desktop computer. In the interactive e-text condition, the written and visual content of the reading remained the same, though the pagination differed: readers had to scroll and click through four screens, again using a desktop computer. All citations in this version included clickable links that brought the reader to the full reference section. One of the figures that appeared in static form in the print book and PDF conditions was interactive in this e-text version, with explanatory text appearing when readers hovered the mouse over certain hotspots (to clarify, this explanatory text repeated and paraphrased information already included in the chapter, rather than providing new content that did not appear in the print or PDF versions). In addition, a static table describing the prisoner's dilemma took an interactive form, allowing readers to play several rounds of the social dilemma. Finally, the five optional end-of-section multiple-choice questions in this version of the text were the same as in the other conditions, but provided readers with immediate correct/incorrect feedback, as well as a single hint to guide readers after an incorrect response (the print and PDF version of the book included an answer key for these questions, but, obviously, no response-dependent hints).

Subsequently, a survey was presented to all participants on a desktop computer, asking them to use a scale of 1 (*not at all*) to 7 (*very much*) to rate how interesting the text was, how clearly it explained concepts, and how well it held their attention. One question each also assessed how much time participants spent on the practice multiple-choice questions at the end of the reading, on the figure, and on the table summarizing the prisoner's dilemma, as well as how helpful each of these elements were to their understanding of the material.

We created a test based on the reading consisting of 20 multiple-choice questions and administered it on the same desktop computer to participants in all conditions. These questions were designed to be comparable to the type that college students encounter on a test in an actual course, assessing factual recognition (13 questions), comprehension/definitional issues (3 questions), and application to novel scenarios (4 questions). Of the 20 questions, five could be considered to be "transfer questions," with direct connection to the end-of-reading practice

questions (though, of course, none of these test questions was identical to the practice questions from the chapter).

Procedure. A research assistant instructed participants that they would complete an assigned reading and then take a test on the material. Participants completed these tasks in a private lab room, accompanied only by the research assistant who sat across the room and timed how long the participant spent reading. All dependent measures—the self-report measures followed by the test—were collected immediately after completion of the reading, via Qualtrics. Participants were not permitted to refer back to the reading while taking the test.

Results

Reading time. For three participants (2 in the interactive e-text condition and 1 in the PDF condition), timer/human error prevented recording of accurate reading time, leaving data from 157 participants on this measure. Across conditions, the average reading time was 15.5 min ($SD = 4.71$). As summarized in Table 2, reading times tended to be longest in the interactive e-text condition, followed by the PDF and print book conditions, but these differences were not statistically significant per analysis of variance (ANOVA), $F(2, 154) = 2.51, p = .09, \eta^2 = .03$.

Self-report data. Table 2 summarizes participants' self-report data by condition. No significant effects emerged across groups for ratings of how interesting, clear, or attention-holding the text was, $ps > .62$. Participants' ratings of how much time they spent on the figure and prisoner's dilemma table (which were interactive only in the interactive e-text condition) and how helpful these two features were did not vary significantly by condition, $ps > .24$.

ANOVA did reveal a significant effect of text modality on participants' ratings of how much time they spent on the end-of-reading practice questions, $F(2, 157) = 3.50, p = .03, \eta^2 = .04$.³

³ Levene's test indicated that the assumption of homogeneity of variance was not met for this measure, $p < .01$. Accordingly, we also conducted a Welch test, which, consistent with the ANOVA, yielded a significant between-groups effect, Welch's $F(2, 102.45) = 4.85, p = .01$. Because of this evidence of heterogeneous variance, we used the Games-Howell post hoc test to compare group means.

Table 2
Dependent Measures by Text Modality Condition in Study 2

Measure	Print book	PDF	Interactive e-text
Reading time (in minutes)	14.64 (4.29)	15.28 (4.69)	16.65 (5.03)
How interesting was text?	5.24 (1.01)	5.06 (1.34)	5.08 (1.08)
How clear was text?	5.91 (.92)	6.00 (.82)	5.83 (1.02)
How well did text hold attention?	4.81 (1.28)	4.85 (1.51)	4.75 (1.06)
How much time did you spend with figure?	3.65 (1.56)	3.69 (1.45)	3.37 (1.28)
How helpful was figure?	4.96 (1.66)	5.04 (1.64)	5.17 (1.42)
How much time did you spend with prisoner's dilemma table?	3.22 (1.50)	3.11 (1.44)	2.75 (1.60)
How helpful was table?	5.54 (1.42)	5.48 (1.45)	5.25 (1.58)
How much time did you spend with practice multiple-choice?	3.26 _a (1.46)	3.35 (1.44)	3.90 _a (1.13)
How helpful were practice multiple-choice?	5.20 (1.76)	4.89 _b (1.82)	5.79 _b (1.27)
Total test score (20 questions)	77.7% (16.6)	75.9% (14.5)	81.5% (13.6)
Transfer questions score (5 questions)	89.1% (14.4)	85.3% _c (16.7)	92.9% _c (13.8)
Nontransfer questions score (15 questions)	74.0% (19.5)	72.8% (16.0)	77.6% (16.6)
Factual recognition questions score (13 questions)	76.9% (18.7)	76.6% (15.7)	82.7% (15.8)
Comprehension/definitional questions score (3 questions)	83.6% (22.3)	80.5% (20.1)	80.4% (21.3)
Application questions score (4 questions)	75.9% (22.4)	70.3% (25.0)	78.4% (18.7)

Note. Standard deviations in parentheses. Means sharing a subscript differ via post hoc test at $p \leq .05$. All items except for reading time and test scores assessed on scale of 1 (*not at all*) to 7 (*very much*). PDF = portable document format.

A Games-Howell post hoc test indicated that the average rating in the interactive e-text condition ($M = 3.90$) differed from the average rating in the print book condition ($M = 3.26$) at $p = .03$ (with the average of 3.35 in the PDF condition not statistically different from either other mean). A similar effect emerged for ratings of how helpful these practice questions were for understanding the material, $F(2, 157) = 4.09$, $p = .02$, $\eta^2 = .05$.⁴ A Games-Howell test indicated that the significant difference was between the interactive e-text ($M = 5.79$) and PDF conditions ($M = 4.89$), $p = .01$ (with the print book average of 5.20 not significantly different from either other mean).

Test performance. Due to programming error, 3 participants (1 in each condition) did not receive all 20 multiple-choice questions, leaving complete test data for 157 participants, as summarized in Table 2. Across conditions, the average score was 15.7 out of 20, or 78.3% ($SD = 15.1$).⁵ Total test scores were highest in the interactive e-text condition, followed by the print book and PDF conditions, but these differences were not statistically significant per ANOVA, $F(2, 154) = 1.84$, $p = .16$, $\eta^2 = .02$. We also conducted an analysis of covariance (ANCOVA) using reading time as a covariate. The covariate did not emerge as a significant predictor of total test score, $F(1, 150) = 2.88$, $p = .09$, $\eta^2 = .02$. The main effect for condition

was not significant in the ANCOVA, $F(2, 150) = 1.27$, $p = .29$, $\eta^2 = .02$.

We further analyzed these data by question type (see Table 2 for all means). First, we examined performance on the transfer questions—those that overlapped in scope with the earlier practice questions. Across conditions, the average score on transfer questions was 4.45 out of 5, or 89.0% ($SD = 15.3$). ANOVA revealed a significant main effect for transfer question performance, $F(2, 154) = 3.37$, $p = .04$, $\eta^2 = .04$. A Tukey post hoc test indicated that the significant difference was between the interactive e-text ($M = 92.9\%$) and PDF conditions ($M = 85.3\%$), with the print book condition ($M = 89.1\%$) not significantly different from either other mean. For the nontransfer items, the average score was 11.2 out of 15, or 74.8% ($SD = 17.5$). While a trend also emerged for scores on these questions to be highest in the interactive e-text condition and lowest in the PDF condition, the differences did not approach statistical significance according to ANOVA, $F(2, 154) = 1.08$, $p = .34$, $\eta^2 = .01$.

⁴ Once again, Levene's test indicated heterogeneous variance, $p < .01$. The Welch test produced a comparable result, Welch's $F(2, 103.62) = 4.11$, $p = .02$.

⁵ For test performance, we report means and standard deviations as percentages to allow for ease of comparison between different question type category.

We also examined test performance separately for questions assessing factual recognition, comprehension/definitional issues, and application to novel situations. For factual recognition questions, the average score was 10.2 out of 13, or 78.7% ($SD = 16.9$); ANOVA did not indicate a significant main effect, $F(2, 154) = 2.11, p = .13, \eta^2 = .03$. For comprehension/definitional questions, the average score was 2.4 out of 3, or 81.5% ($SD = 21.1$); ANOVA did not indicate a significant main effect, $F(2, 154) = 0.40, p = .67, \eta^2 = .01$. For application questions, the average score was 3.0 out of 4, or 74.8% ($SD = 22.4$); ANOVA did not indicate a significant main effect, $F(2, 154) = 1.84, p = .16, \eta^2 = .02$.

Discussion

A novel focus of Study 2 was how text modality influenced participants' reading times and test performance. While some previous findings have indicated that people take longer to read the same text on a screen versus in print format (e.g., [Garland & Noyes, 2004](#); [Kerr & Symons, 2006](#)), our reading times in the PDF and print book conditions were nearly identical. This comparison provided the cleanest test of the influence of modality on reading times, as the PDF consisted of identical text, visual content, and pagination as the print version. Reading times in the interactive e-text condition were somewhat—though not significantly—longer, perhaps not a surprise given the additional features in this version.

We found no evidence of negative screen effects on test performance. Actually, test scores tended to be highest in the interactive e-text compared with the PDF and print text conditions, but these effects were statistically significant only for the transfer questions that overlapped in scope with the end-of-reading practice questions. As noted earlier, we designed our test to be comparable to the type of assessment that college students encounter in their classes, a departure from extant research that has included assessments that are open book or based purely on factual memory. Of course, in several important ways, our participants' experiences still varied meaningfully from those of actual students in an actual course—a fact we will explore in more detail in the General Discussion. Nonetheless, when tak-

ing a college-level test based on reading from a college-level psychology text, our participants exhibited no evidence of being hampered in their comprehension or learning by having read an electronic, on-screen version of their text.

Once again, text modality did not predict differences in participants' reports of how interesting, clear, or attention-holding the reading was. Ratings of the table and figure—which were interactive in the interactive e-text condition—also indicated no between-groups differences. Replicating Study 1, we observed differences for participants' perceptions of the practice multiple-choice questions. Compared with participants who were assigned to static print book and PDF versions, the interactive e-text participants reported spending more time on the questions and finding them more helpful in understanding the material.

General Discussion

Across two studies using different methodologies ([Wilson-Doenges, Troisi, & Bartsch, 2016](#)), we assessed undergraduates' experiences with an electronic psychology text. In Study 1, we examined students from the same course in different semesters and found that those who had been required to use an e-text and those required to use a print book rated the text comparably on a variety of dimensions. These findings stand in contrast to previous research that has reported a student preference for print ([Shepperd et al., 2008](#); [Woody et al., 2010](#)). Of course, there are risks of reading too much into a single data set. But at the very least, our data raise the possibility that this diverging result reflects, in part, that many previous studies finding a preference for print texts did not use as a comparison group an interactive e-text such as the present one—which included embedded video, interactive tables and figures, polling questions with live data, and practice questions with instant feedback.

Study 1 provides some reassuring evidence for instructors considering a move to an e-text but wary of student reaction. Not only did we fail to find that student perceptions of an electronic text are more negative, but we also found that impressions of an interactive e-text tend to be more positive with increased exposure to the modality. Furthermore, we observed at least one specific, potentially beneficial way in which stu-

dents engage with their text differently when it is electronic: they reported spending more time on embedded practice multiple-choice questions when using the e-text, a result that many instructors would welcome among their own students—and for good reason, given the well-documented finding that retrieval practice promotes learning (Karpicke & Aue, 2015; Karpicke & Roediger, 2007).

An advantage of Study 1 was that it examined the perceptions of actual students in an actual psychology course, but its quasi-experimental design did not permit clear answers to the causal question of how textbook modality influences students' perceptions as well as reading and learning outcomes. Accordingly, in Study 2 we randomly assigned students to read from an undergraduate psychology textbook in one of three modalities: print book, static PDF, or interactive e-text. Consistent with Study 1, students in the interactive e-text condition reported spending the most time on the end-of-section practice multiple-choice questions, and also rated these questions as most helpful. In terms of overall test performance, we found no significant differences by condition, though participants in the interactive e-text condition significantly outperformed PDF participants on transfer questions that overlapped with the practice multiple-choice questions from the chapter.

These findings are inconsistent with some previous conclusions, namely, that information tends to be retained and comprehended better when presented in print versus on screen (though several previous studies also have not supported this conclusion, and different studies have used different question types; for reviews, see Ross et al., 2017; Singer & Alexander, 2017b). Again, the method of the present study differed from that of previous work in important ways. Even in a controlled lab setting, we strove to create an environment that more closely approximated the actual experiences of college students: reading a longer passage from an actual psychology text, taking a closed-book test, answering questions that required more than just recognition memory, and including an interactive e-text format.

Despite our best efforts, though, there were several ways in which Study 2 participants' experiences differed from those of students in an actual course. First, our participants had nothing staked on the outcome of their perfor-

mance. Second, while the present design marked an advance over previous studies that have assigned relatively brief readings, the stimulus reading still consisted of less than one textbook chapter—less content than is usually covered on a college test. Third, the reading was completed in one sitting in a controlled setting with an immediate test, which also fails to simulate an actual course.

Clearly, these factors must be taken into consideration in any effort to use the present findings to inform real-life text adoption decisions. That said, we also propose that certain aspects of Study 2 actually may have underestimated potential benefits of the interactive e-text format. One challenge for instructors is how to get students to do their reading to begin with. In our study, participants had little choice; they were in a closed lab room with nothing but the text in front of them. One of the purported benefits of an e-text is its potential to engage students through various features and media, including the ability to listen to the audio of a chapter or read “on the go” via mobile app. Accordingly, some e-text advantages may be more likely to be realized in scenarios with greater variability in whether or not students are drawn to read in the first place—a possibility worthy of future empirical attention. Moreover, to the degree that student enthusiasm for e-texts increases over time, so may the potential for performance benefits as students grow more comfortable with the format.

In closing, our findings do not preclude the possibilities that adopting an e-text will be met with resistance among some students who prefer a print book, or that some students will learn (and test) better after reading a print book. But the present studies indicate that there is also a very real potential for students to enjoy an electronic text as much as a print book, and for their enthusiasm for an interactive e-text to increase with exposure to the technology. We found clear evidence that students spend more time on practice assessment questions when reading an interactive e-text, and find such questions to be more helpful in their mastery of the material when administered in this format. And we observed no decrement in test performance after reading an interactive e-text versus a traditional print book.

Of course, these findings also raise important questions for future investigation. For one, why

do students report more engagement and benefit from midchapter practice questions when using an e-text? Does point-and-click technology make these questions user friendly enough to override the inclination to skip over them? Is the immediate on-screen feedback gratifying and self-reinforcing? Furthermore, to the degree that interactive e-texts can have positive effects on learning outcomes, through what mechanisms might this occur? As well documented in the literature, retrieval practice promotes learning, and our participants paid increased attention to practice questions in the interactive e-text format. Principles of universal learning design also suggest potential benefits when material is represented in multiple means for students. And, as noted above, an interactive e-text could also have beneficial effects to the extent that its format prompts students who might not otherwise complete their reading to engage with the material—a possibility that the present design was not equipped to assess.

There is little question that the rapid development of electronic text features and capabilities will continue to reveal even more avenues for additional inquiry, including those related to new technologies such as audio textbooks and mobile apps. In short, just as it is clear that the e-text is here to stay, it is also clear that today's psychologists, teachers, and students will continue to benefit from a more complete understanding of the evolving technology's advantages, disadvantages, and generalized effects on student perceptions and learning outcomes.

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