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Reading Across Mediums: Effects of Reading Digital and Print Texts on Comprehension and Calibration

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ABSTRACT

This study explored differences that might exist in comprehension when students read digital and print texts. Ninety undergraduates read both digital and print versions of newspaper articles and book excerpts on topics of childhood ailments. Prior to reading texts in counterbalanced order, topic knowledge was assessed and students were asked to state medium preferences. After reading, students were asked to judge under which medium they comprehended best. Results demonstrated a clear preference for digital texts, and students typically predicted better comprehension when reading digitally. However, performance was not consistent with students' preferences and outcome predictions. While there were no differences across mediums when students identified the main idea of the text, students recalled key points linked to the main idea and other relevant information better when engaged with print. No differences in reading outcomes or calibration were found for newspaper or book excerpts.

KEYWORDS

Calibration; computers in education; digital reading; print reading; reading comprehension

Reading across mediums: Effects of reading digital and print

Texts on comprehension and calibration

THE NATURE OF LITERACY is rapidly changing as new technologies enter people's lives and their learning environments (Coiro, Knobel, Lankshear, & Leu, 2008; diSessa, 2000; Dresang & McClelland, 1999; Spiro, DeSchryver, Hagerman, Morsink, & Thompson, 2015; Tyner, 2014). In the last 10 years, a variety of novel text forms (e.g., multimedia books and tweets) and mediums for presenting such texts (e.g., iPad and Kindle) have emerged, which may present new possibilities and new challenges for readers (Alexander & Fox, 2004); that is, features of digital literacy, such as the ability to read and acquire information from graphic representations (i.e., photovisual literacy; Eshet-Alkalai, 2004) and the ability to navigate in the nonlinear medium of digital space successfully (i.e., branching literacy; Eshet-Alkalai & Chajut, 2010) may afford new opportunities for text-based learning. Concomitantly, such digital texts may place unique demands on readers' skillful and strategic processing not typically associated with the processing of printed text (Afflerbach & Cho, 2009; Hartman, Morsink, & Zheng, 2010; Kingsley, 2011; Kuiper, 2007; Spires & Estes, 2002).

Whatever the processing affordances and demands, digital texts are inevitabilities in the lives of students being educated in postindustrial societies (Gray, Thomas, & Lewis, 2010; Purcell, Heaps, Buchanan, & Friedrich, 2013). For instance, Zickuhr, Rainie, Purcell, Madden, and Brenner (2012) claimed that 43% of Americans and 48% of those between the ages of 18 and 29 read lengthy texts, such as newspapers or books, digitally, and these percentages are expected to increase exponentially

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(Stephens, 2014). Further, many international and national assessments of students' literacy are not only being delivered digitally but are also including affordances that are more specific to digital media, such as websites or links (Coiro, 2009; Coiro & Dobler, 2007; Leu, Coiro, Castek, Hartman, Henry, & Reinking, 2008). Thus, the effects on students' comprehension of these digital texts, vis-à-vis print text, demand systematic exploration. This study sought to more clearly articulate differences that might exist in reading comprehension when mature readers access differing text types in digital and print forms. In addition, we endeavored to explore the efficacy judgments that students make regarding their text processing, as well as the degree to which these students are able to judge their comprehension facility accurately across mediums (i.e., digital and print) and text types (i.e., newspapers and books).

The view of reading comprehension that frames this study conveys the nature of comprehension as an active, constructive, meaning-making process (Goldman, 2015; Graesser, 2007; Kintsch & Kintsch, 2005; McNamara, 2012) in which the reader, the text, and the activity play a central role (Alexander & Jetton, 2002; Pearson, 2001). Moreover, consistent with Kintsch's (1988) construction-integration model of comprehension, readers are expected to form connections between their own prior knowledge and the ideas expressed in or inferred by the text per se. Within this theoretical framework, there is also an acknowledgment that the medium and type of text could well translate into differences in text processing and comprehension performance.

The challenges and possibilities of reading digital and print texts

Our goals of understanding the effects of reading digital and print texts on students' comprehension and calibration were informed by prior research in this domain of inquiry (e.g., Noyes, Garland, & Robbins, 2004; Sutherland-Smith, 2002; Zambarbieri & Carniglia, 2012). Within this literature, differences across mediums have been found in terms of speed of processing, text recall, and reading comprehension (e.g., Kerr & Symons, 2006; Mangen, Walgermo, & Brønnick, 2013). For instance, in a study involving 72 Grade 10 students in Norway who read text digitally or in print, Mangen et al. (2013) found that students who read print versions scored significantly higher in reading comprehension than those who read digitally. Similarly, Kerr and Symons tested the recall of 60 Grade 5 students in Canada who each read two passages, one digitally and one in print. What the resulting data indicated was that participants recalled more from the print text than from the digital text. Further, a survey by Rideout, Foehr, and Roberts (2010) suggested that those who read in print reported that they were less likely to multitask than when reading digitally.

Also of some concern, researchers have reported that even competent readers often treat texts as authorless, decontextualized constructions (e.g., Fox, Dinsmore, & Alexander, 2007; Maggioni & Fox, 2009) and seemingly accept the veracity or truthfulness of whatever is encountered in text (Grossnickle, List, & Alexander, 2012). Such concerns may well be exacerbated by digital contexts in which information can be particularly elusive and where inaccurate or misleading content seems unavoidable and often unchallenged (Lankshear & Knobel, 2006). Consequently, more effort may be required to unearth relevant source data or to seek corroborating or confirming evidence within the vast universe of digital information (Braasch, Bråten, Strømsø, Anmarkrud, & Ferguson, 2013).

Moreover, researchers have reported that repeated or intensive engagement in digital multitasking may contribute to a more superficial processing of the text (Levine, Waite, & Bowman, 2007; Ophir, Nass, & Wagner, 2009; Wallis, 2010). For instance, Liu et al. (2009) reported that when working on a digital device, readers switched activities every 3 to 10 minutes. Therefore, these researchers argued that it seemed improbable for these readers to engage in deep thought when they are switching so often during the text processing. Even in those instances when readers are not switching activities, they may be more apt to scan digital texts than to read them deeply (Rowlands et al., 2008; Wallis, 2010). It is also conceivable that the very wealth of information that resides in the digital universe, combined with the increasing speed and ease of access, may overwhelm intentions to process such digital content critically or analytically (Ophir et al., 2009; Wallis, 2010).

Alongside these aforementioned differences in readers' processing of digital texts, there are visual ergonomic characteristics of digital media that must also be entered into the comprehension calculus.

Specifically, visual legibility of digital texts, basic to word processing and comprehension, is influenced by several factors, including text size, screen resolution, backlighting, and luminance contrast (Dillon & Emurian, 1995; Lee, Ko, Shen, & Chao, 2011). And such factors can result in physical and perceptual differences for digital versus print reading. For example, LCD computer screens, the most common method of reading digitally, are found on most desktop, laptop, and handheld tablets such as an iPad. Researchers have found that these screens might contribute to visual fatigue as a result of the lighting source (e.g., Benedetto, Drai-Zerbib, Pedrotti, Tissier, & Baccino, 2013; Mangen et al., 2013). Further, Garland and Noyes (2004) determined that other features of a LCD screen, such as its refresh rate, contrast levels, and fluctuating light, can interfere with text recall.

Yet another perceptual factor that might play into processing differences between digital and printed text has to do with sequential versus continuous reading—that is, whether a reader must scroll frequently between portions of text or whether reading progresses in a more uninterrupted fashion (Proaps & Bliss, 2014). From the available research, there is evidence that frequent scrolling increases the cognitive demands on readers and, thus, may negatively affect recall (Wästlund, 2007; Wästlund, Reinikka, Norlander, & Archer, 2005). The inclusion of hyperlinked materials can also increase cognitive demands when individuals are processing digital texts (DeStefano & LeFevre, 2007). Moreover, print texts allows readers to see and feel the spatial extension and physical dimensions of the text, and the material of the paper provides physical, tactile, and spatiotemporally fixed cues to the length of the passage (Mangen, 2006, 2010; Sellen & Harper, 2002). In light of the potential for such scrolling or the inclusion of hyperlinks to further complicate the processing of digital texts, we elected to control for those factors in this investigation by ensuring that relevant text was fully available to readers without scrolling and that no hyperlinked materials were incorporated. However, for practical reasons, the digital texts for this study were presented on LCD computer screens.

The visual ergonomic differences between digital and print texts notwithstanding, the story regarding media is not one sided. In fact, potential benefits for digital reading have been empirically documented (e.g., Arsham, 2002; Coiro et al., 2008; Loucky, 2005; Reeves, 2004). For one, strong preferences for digital texts among individuals of varying ages have been reported (Prensky, 2013; Reinking et al., 1998; Rideout et al., 2010). Such preferences stand as an indicator of the motivational benefits that might be accrued from reading digitally. In support of this contention, Zickuhr et al. (2012) found that people who owned e-readers read on average twice as many books as those who read only in print. When surveyed on why they preferred e-readers, participants reported that digital texts provided speedier access and greater portability than print. The benefits of accessibility and portability have been noted in other studies across ages and settings for reading (Creel, 2008; Stephens, 2010; Waycott & Kukulska-Hulme, 2003). Rideout et al. (2010) further documented that the amount of time young people ages eight to 18 spend reading printed texts has decreased about 5 minutes between 1999 and 2009, suggesting a trend toward even more digital reading in the years to come.

Beyond self-reported preferences for digital texts, there is evidence that today's students perceive of themselves as *digital natives* armed with the necessary skills to manage the demands of digital reading (Palfrey & Glasser, 2013; Prensky, 2013). Such self-efficacy judgments would also seem to bode well for students' engagement with and learning from digital texts, and there is some evidence to support students' self-judgments (Farah & Maybury, 2009; Housand & Housand, 2012; Koh, 2013). As a case in point, Kerr and Symons (2006) determined that students in their study were able to navigate digital passages more efficiently than print versions. Further, Salmerón and García, (2012) found that when students read digital text that included hypertext, they were able to better integrate the material than when reading the same material in print. Yet, there are others who question whether students' judgments as to their online learning capabilities are as well developed as the notion of *digital native* suggests (Fried, 2008; Kolikant, 2010).

Yet, another reason for more positive views of reading digitally pertains to the transfer of reading processes, skills, and strategies that has been reported not just between digital and print media (Ackerman & Goldsmith, 2011; Norman & Furnes, 2016; Noyes & Garland, 2008; Reinking, 1988) but also between students' reading and listening comprehension (Kendeou, Bohn-Gettler, White, & van den Broek, 2008; Kendeou, van den Broek, White, & Lynch, 2007). For example, studies have concluded

that comprehension skills are similar across different communication mediums (e.g., in print or audio-visually; Kendeou et al., 2008). Further, adults' ability to comprehend written language correlates highly with their ability to comprehend spoken language (Gernsbacher, Varner, & Faust, 1990). Thus, there is some expectation that the reading and comprehension processes of the college readers in this investigation might well carry forward across digital and print mediums, especially given their familiarity with reading digitally for academic purposes.

Lingering issues

In light of the burgeoning presence of digital reading and the growing literature that explores the processing of digital texts in comparison to their print counterparts, there are significant questions that merit systematic examination. While Ackerman and Goldsmith (2011) found differences in memory, comprehension, and calibration across mediums when reading expository texts by similar-aged readers, many relevant questions remain unanswered. Although their work examined calibration when reading in digital and print forms, it failed to address a critical variable, text type. Further, Ackerman and Goldsmith's (2011) study used multiple-choice questions assessing memory and understanding of the text as their measure of comprehension. Our study design assesses comprehension through three levels of short-construction questions, eliminating an individual's ability to guess or memorize on comprehension assessment. Further, we crafted a more advanced study design that accounts for individual prior knowledge of the passage being read. Our design also deliberately controlled for scrolling, a navigation issue commonly associated with digital reading, by limiting the passage length. Not only is scrolling controlled for in our study, but the texts were presented as a reader would see them outside of the controlled setting (i.e., a newspaper passage in the exact layout they would see it on a news website), whereas Ackerman and Goldsmith's (2011) digital passages were presented in a word document.

For one, it is not apparent whether students' expressed preferences for digital or print text would vary as a consequence of the type of material to be processed. For instance, there are some who might contend that college students, the focus of this investigation, would voice a preference for the reading of newspapers versus book excerpts in print rather than digitally (De Waal, Schönbach, & Lauf, 2005). But the pattern in voiced preferences by text type largely remains an open question within the literature.

What is also unresolved within this expanding literature is whether students' judgments as to their comprehension abilities under digital and print conditions (i.e., their efficacy judgments) would hold up when compared to actual comprehension performance. This contrast between predicted and actual performance is what has been called *calibration* (Alexander, 2013; Fischhoff, Slavic, & Lichtenstein, 1977; Glenberg, Sanocki, Epstein, & Morris, 1987). Overall, the calibration of children and youth for a range of academic tasks and subject-matter domains has often been found wanting (Chen & Zimmerman, 2007; Hacker, Bol, & Bahbahani, 2008; Pajares & Miller, 1997), suggesting that students are not particularly astute in critically judging their learning or level of performance.

While acknowledging that the past decades of metacomprehension research have not painted the most flattering picture of calibration among learners (Dunlosky & Lipko, 2007), including college students (Winne & Jamieson-Noel, 2002; Winne, Jamieson-Noel, & Muis, 2002), there remains the possibility that the students in the current investigation will be better attuned to their ability to comprehend under differing mediums than has typically been reported. As with prior research (Ackerman & Goldsmith, 2011; Butler, 1998; Graham & Harris, 1989; Lin, Moore, & Zabrucky, 2001), we considered calibration in relation to undergraduates' posttask predictions as to the medium (i.e., digital versus print) in which they had performed best and then compared those predictions to their actual performance. What was different in this instance was that the students had the opportunity to gauge their comprehension under both medium conditions with comparable reading content before rendering judgments. Further, participants had the opportunity to respond to comprehension questions that varied in specificity (e.g., main idea versus key points). Thus, we wanted to ascertain whether these task features would translate into better calibration for these mature readers.

Another area that merits exploration is the role the text type plays in comprehension and calibration abilities. Research suggests that different preferences for digital or print text arise as a consequence of

the type of material processed (e.g., Creel, 2008; Waycott & Kukulska-Hulme, 2003). Further, the reading framework report from the National Assessment of Educational Progress (National Assessment Governing Board, 2013) indicates that reading behaviors, such as making sense of sentences and paragraphs and recognizing and using features of text, can vary in relation to text type. As a result, NAEP includes two broad categories of text type in its reading assessment: literary texts (such as book excerpts) and informational texts (such as newspaper articles). In addition, newspapers have been specifically referenced in the literature with regard to medium preferences, with some indication that individuals prefer to read the newspaper in print as opposed to digitally (De Waal et al., 2005). Book excerpts, similar to segments of textbook chapters, were thus selected as the alternative text type in this study due to their growing presence in college classrooms (Jenkins, Kelley, Clinton, McWilliams, & Pitts-Wiley, 2013; Schoenbach, Greenleaf, & Murphy, 2012).

The reading comprehension task used in this study had participants respond to three short-construction questions immediately after reading a passage. We elected to assess comprehension using short-construction questions in light of positive evidence regarding the merits of this format, such as its broader applicability and the richer information garnered from generated versus selected response formats like multiple-choice items (Pearson & Hamm, 2005). Further, short-construction questions eliminate random guessing as a response option (Burton, 2001). In addition, well-known national assessments such as the National Assessment for Education Progress (NAEP; National Center for Education Statistics, 2013) and the Stanford Achievement Tests (SAT-9; Traxler, 2000), as well as a number of statewide reading tests, have long used short-construction questions to delve deeper into students' reading comprehension (Sarroub & Pearson, 1998). Thus, given the aforementioned factors, as well as the short length of the passages and the college level reading abilities of participants in this study, we elected to employ short-construction questions in the current study.

In the exploration of the aforementioned issues, we also wanted to probe more deeply into whether differences in the accuracy of self-judgments would emerge when the nature of comprehension being assessed varied. Specifically, there is some research to suggest that the speed of processing associated with digital reading may have more bearing on the recall of details within text than on the identification of the main idea (Ackerman & Goldsmith, 2011; Williams & Rowlands, 2007). This collection of lingering issues, therefore, led to the following research questions that guided this investigation:

1. What espoused preferences for reading digitally and in print do undergraduate students voice and do those preferences vary as a consequence of text type?
2. After accounting for topic knowledge, to what extent do undergraduate students' judgments as to their ability to comprehend digital and print texts correspond to their actual comprehension performance?
3. Is there any association between stated preferences or calibration accuracy when undergraduates are called upon to identify the main idea, key points, and other relevant information?

Method

Participants

Participants for this study were 90 undergraduate students enrolled in human development and educational psychology courses at a large mid-Atlantic university. The sample was 68.3% female with a mean age of 19.28 *(SD* = 1.24*)* years. The sample was majority White (57.4%), with 14.9% self-reporting as Asian and 14.9% self-reporting as African American, and represented a wide variety of majors, primarily in the social (44.7%) and natural (29.8%) sciences.

Our decision to focus on undergraduate students enrolled in human development and educational psychology courses was based on several considerations related to the existing literature, the nature of the task, and the texts being read. For one, a recent review of the literature pertaining to digital and print reading indicated that over 75% of the identified studies involved undergraduate readers (Singer, 2014). Therefore, in order to compare outcomes of the current investigation to the extant literature, we felt that undergraduate readers would serve our goals best. In addition, individuals of this age level

would fit the profile of *digital natives* (Prensky, 2001). As a result, we expected this population to be particularly opinionated about reading in the digital, as compared to print, medium.

Moreover, as we will discuss later, we chose texts that pertained to childhood ailments—topics that we regarded as pertinent to college students enrolled in human development or educational psychology courses. Finally, because of our intention to investigate varied text types, specifically book excerpts and newspaper articles, we wanted participants who would have had sufficient exposure to these textual forms.

Experimental texts

Eight experimental texts about childhood ailments were used in this study. This topic area was chosen for several reasons. First, childhood health topics would presumably be of interest to the sample, undergraduate students in a human development or educational psychology course, because the passages pertain to topics relevant to human learning and development. Further, the topic of childhood ailments was germane to the participants' coursework without being a topic that would specifically be covered in those courses.

The four book excerpts were from *Healing the New Childhood Epidemics: Autism, ADHD, Asthma, and Allergies—The Groundbreaking Program for the 4-A Disorders* (Bock & Stauth, 2008). The four newspaper articles were from the *New York Times* and dealt with one of the same four childhood health topics (i.e., ADHD, allergies, asthma, and autism). All texts were of similar length (approximately 450 words) and readability (approximately 8.5 grade level; Fry Readability: Fry, 1968). Prior to administration, the eight passages were modified to ensure that the frequencies of key points and other relevant information were held constant across texts. As a result, each passage centered around a clear main idea, which did not appear explicitly in any of the passages and, thus, had to be inferred by the reader. Further, each passage contained four key points, which were text-based idea units or phrases linked directly to the main idea. Lastly, in addition to the key points, each passage contained five additional text-based idea units or phrases that could be recalled.

For the study, each participant read four texts in total: two texts from each medium (i.e., digital and print) and two texts from each text type (i.e., book excerpt and newspaper) presented in counterbalanced order. For example, one participant read in the following order: digital book excerpt, print newspaper, print book excerpt, and digital newspaper. The next participant read print newspaper, print book excerpt, digital newspaper, then digital book excerpt to negate any possible order effects.

Measures

Students first completed a demographic survey and then four additional measures: an assessment of topic knowledge, a medium-preference survey, a medium-usage questionnaire, and a comprehension assessment.

Topic knowledge

To ascertain students' familiarity with the topics of the reading tasks, students were asked to rate their level of knowledge of the four topics covered in the readings (i.e., childhood ADHD, allergies, asthma, and autism). These ratings were made on a 100 mm scale that ranged from 0 (*no knowledge*) to 100 (*expert*). For example, respondents were asked to "Rate your knowledge on the subject of childhood ADHD." If students marked their knowledge of childhood ADHD at the 25 mm line, they received a score of 25 on the topic knowledge measure for childhood ADHD. The students repeated this three more times for the three remaining topics (childhood allergies, asthma, and autism).

Medium preference

Upon completing the topic knowledge measure, students were asked to complete a medium preference survey. This survey consisted of seven task situations for which students were asked to judge whether

they preferred to complete each task using a digital or print text. For example, students encountered the following situation:

You want to read the Sunday newspaper.

a. Prefer to read digitally
b. Prefer to read in print
c. No preference

Participants medium preference score was calculated by tallying the frequency at which they indicated digital, print, or no preference for the seven task situations.

Medium usage

Upon completing the medium preference task, students were asked questions about how frequently they had used digital and print mediums in the past academic year. For example, as seen in the following situation, they were asked how frequently they used digital texts for college coursework:

In the past academic year, have you used digital textbooks for your course work?

a. Yes, for all of my courses
b. Yes, for some of my courses
c. No

Reading comprehension task and scoring

We were interested in examining the effects of medium (i.e., digital and printed) and text type (i.e., book excerpt and newspaper) on students' comprehension. Prior to reading, participants were told they would read a passage and be asked questions about the main idea, key points, and other relevant information after reading and would not be able to access the text when responding. To assess their comprehension, students responded to three short-construction questions immediately after reading each of the texts that corresponded to the instructions detailed prior to reading. The questions were presented in the same medium in which they just read. For example, after reading about childhood allergies digitally, participants were asked to answer the following questions online:

1. Explain the main idea of the passage.
2. List the key points of the passage.
3. Jot down any other relevant information you may remember.

Scoring rules were determined a priori for the reading comprehension measure. The main idea and the key points within each passage had been identified and verified by the first author and two independent readers, along with the scoring criteria for each of the three question types. Specifically, the main idea question was scored on a 0–2 scale for each passage read, for a maximum score of 8. A score of 0 was earned if the student wrote nothing or a main idea that was unrelated to the passage. To earn one point, the response had to be text relevant but not fully comprehensive of the main idea. For example, if the main idea were "childhood asthma can be treated by knowing the antecedent triggers of inflammation," a score of 1 would be awarded if the answer given were simply "asthma." To earn 2 points, students had to record a main idea that was text related, generally accurate, and fully comprehensive.

The two remaining questions pertaining to key points and other relevant information were scored on a 0–1 scale. This scale was applied to each piece of recorded data. To earn a point, responses listed had to be text based and accurate. For the "key points" question, responses were scored against the preidentified list, allowing participants to earn one point for each key point listed. No points were subtracted for missing or incorrect key points listed. Thus, participants could earn up to four points per passage for key points, with a possible maximum key-point score of 16 points for all four texts.

Mirroring the question regarding key points, the final question asking for other relevant information was scored under the same guidelines using a preidentified list of statements taken directly from the passage or paraphrased that were not listed in the main idea or key-points questions. For the other relevant information questions, students could earn up to five points for each text. Again, no points were subtracted for missing or incorrect relevant-information points listed. This scoring method resulted in a maximum score of 20 points for the two digital and two print texts.

To illustrate better the nature of the comprehension questions and their scoring, the modified book excerpt dealing with childhood asthma, along with the scoring guide, appears in the Appendix.

To establish interrater agreement, the first author and a second rater scored all responses independently and their scores were compared. Prior to this independent scoring, however, the first author developed a set of training text materials and simulated responses that paralleled those read in the actual study. Once the second rater displayed an understanding of the scoring criteria and was proficient at scoring above a 95% level, the actual data set was introduced. Interrater agreement for the full data set, scored independently, was 98.5%. Any disagreements were resolved through discussion.

Medium performance

As a means of assessing students' calibration, we asked them to judge their performance under digital and print mediums. Specifically, the students answered the following question:

In which medium do you believe you performed best?

a. Digital
b. Print
c. No difference

Procedure

The study was conducted outside of class in a designated area. Students completed the demographics survey, followed by the topic knowledge measure, and the medium preference survey digitally. Then, they moved on to the reading comprehension portion of the study. Students were given their first text passage (i.e., book excerpt or newspaper) in either print or digital form and instructed that they would be required to answer questions about the passage from memory. When they indicated they had completed the reading, students were presented with the reading comprehension task in the same format (i.e., digital or print). They then answered the reading comprehension questions in the same format as their reading. They were allowed to record their responses using bullet points or connected discourse and were given unlimited time to complete the task.

The reading passage and reading comprehension measure procedure described was repeated three times with variation as to medium in accordance with the condition to which the student was initially randomly assigned (e.g., print book, digital newspaper, digital book, and print newspaper). After all four readings and associated comprehension questions were completed, students responded to the question concerning in which medium they performed best. The average time for task completion was approximately 80 minutes.

Equipment

Participants completed the digital portions of the study using a 15" LCD monitor at a resolution of 1280 × 1024 pixels. The computers were familiar to the subjects as they are the computers the students use throughout the university on a daily basis, which was confirmed prior to administration. The texts presented digitally were presented as PDF files, read using Adobe Reader for Windows. The print texts were read from the paperback book, where the modified passage was inserted to appear authentic. The designated passage was bookmarked and only relevant sections are visible to the reader.

Results and discussion

Topic knowledge

Our first step in this analysis was to examine the potential effects of topic knowledge on students' comprehension performance. We did so by determining whether topic knowledge was significantly related to students' performance on the comprehension measure. Given that differences in topic knowledge across ailments was found to be statistically nonsignificant ($F_{(3,86)} = 1.19$, $p = .09$), topic scores were collapsed to produce a single topic knowledge score, which comprised the four self-reported scores (0–

100) for each childhood ailment to total a final overall topic knowledge score from 0 to 400 (see Table 1).

The overall performance of this measure reinforced our expectation that students generally would not be well versed in these topics of childhood ailments ($M = 145.26$, $SD = 93.23$), although some students did in fact, display higher levels of topic knowledge than others (range 0–360). The distribution of scores was positively skewed (see Figure 1), showing that as expected the majority of participants were not very knowledgeable about the selected topics. Topic knowledge was determined to not be significantly related to reading comprehension scores, $r = .13$, $p < .01$. Therefore, no adjustment in the comprehension scores was required.

Medium preference

Next, we sought to address whether there would be a marked preference among the undergraduate students in our study for the use of digital or print medium when engaged in various reading tasks. For all seven situations, the majority of students preferred to read digitally. However, some situations resulted in more students selecting print or reporting no preference than others. For example, the situation, "You want to read a tabloid magazine while on vacation," had the lowest percentage of students favoring the digital medium (46.7%), while many chose read in print (37.8%) and others chose no preference (15.6%). The situation that stated, "You are reviewing a reading on World War I for an upcoming history exam," ended up being the situation with the most support for reading digitally (73.3%), while 21.1% preferred print and only 5.6% of students reported that they had no preference.

The situation stating, "You are reading the news for the top stories," resulted in 56.7% of the students selecting to read digitally, while 25.6% chose the print medium, leaving 17.8% selecting no preference. Interestingly, a second situation involving newspapers, "You want to read the Sunday newspaper," had students leaning much more strongly toward reading digitally. For this situation, 74.4% chose the digital medium, while only 21.1% chose print and 4.4% reported having no preference.

Examining the participants individually, 7.8% stated that they preferred to read in the digital medium no matter the situation presented. Only one participant indicated that s/he preferred to read in print no matter the situation. None of the students who participated responded that he or she had no medium preference for all seven situations. This outcome is perhaps not surprising given that these students have been described as "digital natives" (Prensky, 2001).

Medium usage

`In order to ascertain the students' experiences with digital texts, four questions regarding medium usage were asked. The first question queried: "Do you own a tablet or e-reader device?" For that

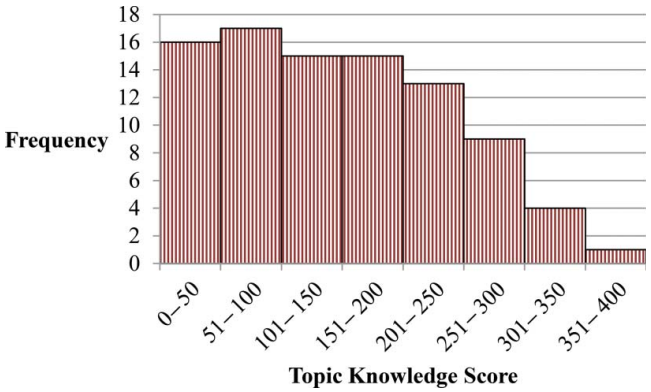

Figure 1. The bar graph displays the participants' self-reported topic knowledge. This figure illustrates that students generally rate their knowledge of various childhood ailments as rather low.

Table 1. Self-Reported topic knowledge.

Topic	Mean score	*SD*	Maximum score
Overall	145.26	93.23	400
ADHD	35.90	23.87	100
Allergies	36.80	24.37	100
Asthma	36.94	23.95	100
Autism	35.62	24.96	100

question, 87.8% of the sample responded affirmatively. Next, participants responded to how frequently they accessed digital texts. Not surprisingly, 95.6% of the sample accessed text digitally at least once a day. When asked about the frequency with which they access printed texts, 81.1% reported reading in print at least once a day. However, 24.4% of respondents selected "as little as possible" to this question. Within the classroom, 64.4% of students were currently using a digital textbook for one or more courses.

Comprehension across mediums

For the question dealing with the main idea, the majority of participants (60%) were able to identify the main idea, at least in partial form, while another 35% provided fully accurate and comprehensive restatements of the designated main ideas. The remaining 5% of respondents either produced an unclear response or failed to respond at all to the question. These patterns did not vary whether the texts were processed in print or digitally. In order to ascertain whether there were differences in comprehension by medium or text type, a 2 (medium) × 2 (type) ANOVA was run, revealing that there were no main effects for the main idea question for medium or for text type ($F(1) = 2.99$, $p > .05$). The descriptive statistics for the three comprehension questions by medium are displayed in Table 2.

For the comprehension question pertaining to key points, a 2 (medium) × 2 (text type) ANOVA was run and analysis revealed an interaction between medium and type ($F(1) = 8.96$, $p < .05$, $\eta^2 = .05$), as well as a main effect for medium ($F(1) = 44.94$, $p < .001$, $\eta^2 = .06$). However, there was no main effect for text type, ($F(1) = 1.36$ $p > .05$). As indicated in Figure 2, performance on the key-points question was higher for both text types when reading in the print medium, but the disparity in scores between mediums was exacerbated when reading a book excerpt.

When it came to the final comprehension question pertaining to other relevant information, a 2 (medium) × 2 (text type) ANOVA was run, revealing a main effect for medium ($F(1) = 44.64$, $p < .001$, $\eta^2 = .09$). However, there was no main effect for text type on outcome and no significant interaction ($Fs(1) = 2.11$, $ps > .05$). Unlike the key-points comprehension question, the difference in performance across mediums was consistent, no matter the text type. Thus, when reading a book excerpt or newspaper article, students were better at recalling "other relevant information" when reading in the print versus the digital medium.

Table 2. Comprehension performance by question type and by medium.

Medium	Question type	Mean score	*SD*	Maximum score
Print				
	Main idea	2.64	.38	4
	Key points	5.61	3.83	8
	Other information	7.13	2.91	10
Digital				
	Main idea	2.56	.23	4
	Key points	5.19	4.31	8
	Other information	6.42	3.18	10

Note. Scores and maximums are combined scores from both passages read in each medium type.

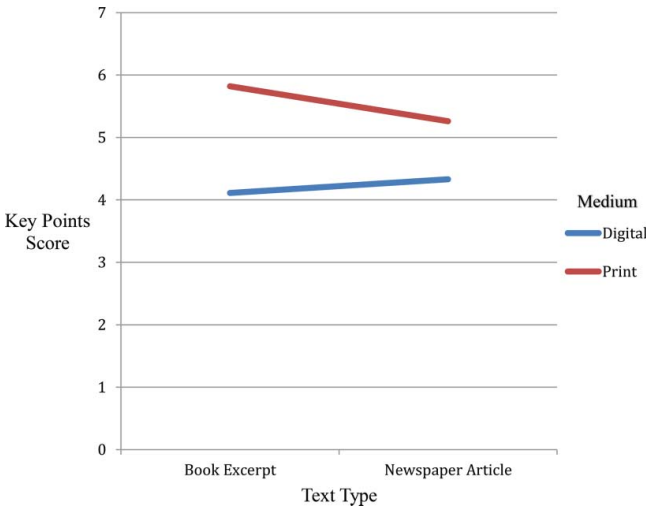

Figure 2. The graph displays the interaction between medium and text type on comprehensions of key points. As the figure illustrates, when reading a book excerpt, the medium in which the excerpt was read (i.e., digital or print) had a significant impact on key-point comprehension performance.

Performance judgments and calibration

When asked to judge the medium in which they performed the best, the majority of participants (69%) chose the digital medium. By comparison, 18% of participants judged the medium in which they performed the best to be the print medium, while the remaining 13% felt that their performance was equivalent across the two mediums. The descriptive data of predicted performance and demonstrated performance by medium type are shown in Table 3. A chi-square test of independence was used to determine whether there was a difference in observed and expected judgments of performance. In spite of their marked preference, we found that more students than expected demonstrated stronger comprehension in the print medium than in the digital medium, X^2 (1, $N = 90$) = 6.60, $p < .01$. Such outcomes indicate that the students in this investigation were generally poorly calibrated with regard to the medium under which they comprehend better. Far more students than would be expected by chance presumed that they would be better at performing in digital medium but, in reality, comprehended better in the print medium.

Conclusions and implications

This study was motivated by the pervasiveness of digital media in the lives of young people. With technologies ever-increasing presence inside and out of the classroom, today's learners are presented with more options for reading than ever before (Stephens, 2014). Consequently, there has been an increase of research in the area of reading in the digital medium (e.g., Hartman, Morsink, & Zheng, 2010; Jabr, 2013; Ponce & Mayer, 2014). Trends in the literature show that readers, especially those who classify themselves as *digital natives* (Prensky, 2013), prefer reading in the digital medium perhaps due to the

Table 3. Results of chi-square test of calibration performance by medium type.

		Predicted performance	
		Digital *f* (%)	Print *f* (%)
Demonstrated performance	Digital *f* (%)	60(66.7%)	13(14.5%)
	Print *f* (%)	9(10%)	8(8.8%)

ease and accessibility the Internet affords (Singer, 2014). Further, those who read via the digital medium may be reading more than their peers reading in the print medium (Zickuhr et al., 2012). However, research specifically examining reading comprehension has produced mixed results in terms of which medium is best for understanding the text (e.g., Arsham, 2002; Coiro et al., 2008; Loucky, 2005; Reeves, 2004). While some studies have found passages can be read more quickly in the digital medium (Kerr & Symons, 2006), other studies have found greater gains in reading comprehension when reading the passage in print form (Mangen et al., 2013).

Despite the digital medium's apparent ubiquitousness and noted favorability among digital natives, we cannot operate on the assumption that its prevalence or even stated preference alone results in equal or better comprehension than what has been demonstrated for print text. It would be irresponsible to simply assume that those who perceive themselves as digital natives are in fact well equipped to understand what was read in a digital environment. Despite the noted preference for digital texts (Prensky, 2013; Reinking et al., 1998; Rideout et al., 2010), no matter the task and the benefits the medium offers (e.g., portability and speed), the literature is not clear as to whether the affordances of reading digitally translate into consistent positive learning outcomes for the reader (Singer, 2014). Further, it remains unclear how well aware digital natives are of the affordances of or disadvantages present within the digital medium.

This study sought to address the aforementioned questions and concerns regarding perceptions and learning outcomes. While the current study confirms some of the findings in the literature regarding students' preference for digital texts (Coiro, 2009; diSessa, 2000), it extends prior research in several additional ways. First, it allowed for within-subject examination of performance on equivalent reading tasks across mediums and across text types. As such, it provided a more detailed picture of undergraduates' espoused medium preferences vis-à-vis their comprehension performance—that is, their calibration. The outcomes call into question even mature and digitally experienced readers' efficacy judgments. Moreover, the current study revealed potential differences in comprehension across mediums, even taking into account students' self-reported knowledge of the reading topics, which has yet to be explored. Further, the current study served to more effectively locate those differences (e.g., main ideas versus key points or other relevant information). From these data, therefore, we found that medium mattered little for these undergraduates when only the big idea or gist was required. The picture became more complete when more specific information was requested. In light of the nature and scope of reading digitally in students' lives, including the increasing presence of digital textbooks (Gray, Thomas, & Lewis, 2010), this particular finding merits further exploration.

A future study should address the role of feedback on calibration judgments. It remains to be seen whether students would be willing or able to adjust their expectations and their performance if they were made aware of the discrepancy between the stated preferences and demonstrated performance for similar-aged populations. Feedback has been shown to have powerful effects on students' learning and performance (Hattie & Timperley, 2007), so perhaps feedback would result in more-selective use of text mediums by students and more accurate metacognitive performance judgments. Additionally, feedback has been shown to be extremely effective for this study's population—undergraduate students (Koriat, Ma'ayan, Sheffer, & Bjork, 2006). On the other hand, the wealth of digital texts and the ease and speed of access may prove too seductive for students, even if comprehension and recall suffer to some extent.

Another area for future inquiry pertains to the age of the reader. While this study deliberately sought to examine digital natives, one must question whether the patterns found would remain true across different ages. For example, what would we find with much younger readers who have grown up with digital reading? What about an older adult who did not learn to read in the digital age, who may have differing views of the digital medium and more-attuned judgments of performance when reading in print?

Future work should also attend to the nature and specificity of the calibration task itself. Specifically, the post hoc judgment of the learning task used in this study could be refined. As recommended by Dunlosky, Rawson, and Middleton (2005), matching grain size between the task and judgments of learning may produce a more aligned metacomprehension judgment for the learner. Further, given

that metacomprehension research has almost exclusively focused on global judgments of learning, it would prove informative to gauge readers' judgments of learning for each comprehension question type asked (Dunlosky et al., 2005). Future work should address calibration at each question type to see if results are consistent with those reported herein.

There are several possible explanations for why students' in the present study performed better in the comprehension questions when reading in the print condition. For one, the differences could be related to the navigational issues within the document. A navigational issue to consider is the nature in which the mediums determine one's access to the texts in their entirety. Research has suggested that readers often recall where in a text a certain piece of information appeared (e.g., toward the bottom of the page; Rothkopf, 1971; Zechmeister & McKillip, 1972). While the current study controlled for the navigation issue commonly associated with digital reading (i.e., scrolling), research suggests there are other factors associated with reading digitally that restrict users' ability to mentally reconstruct what was read (Cataldo & Oakhill, 2000), and so, the interaction found between medium and text type on key-point comprehension warrants further examination. When reading book excerpts, students performed significantly better in print than they did digitally.

Perhaps this outcome reflects the navigational cues that print affords or the inherent challenges with reading digitally, such as refresh rate, contrast levels, and fluctuating light (Garland & Noyes, 2004). A suggestion for future research could be to replicate the findings of our study and have the subjects read longer texts that require scrolling and page turning, as it might be assumed that challenges pertaining to navigation may increase with this added demand. Although research has shown that the digital medium comes with perceptual processing challenges (Baccino, 2004), it is impossible to determine from the data of the current study whether visual fatigue contributed to poorer reading-comprehension performance in the digital medium. Hence, we cannot ascertain whether the visual ergonomics of the computer screens had any impact on the students' performance. In future studies, it would be particularly interesting to employ digital measures, such as eye tracking, alongside think-alouds. Conducting a comparable study with the addition of eye tracking data and think-alouds obtained as readers are engaged with the text would allow for richer data about a participant's processing for both print and digital mediums and for corroborating evidence regarding their calibration judgments.

These limitations notwithstanding, this study has several implications for educators. For one, educators need to be sensitive to the affordances and disadvantages offered by digital and print reading. Students cite the ease of access and range of materials at hand to be alluring benefits of the digital medium. And, in fact, they may be correct. It seems that the affordances offered by the digital medium may sometimes be worth the potential costs. Sadly, for some students today, simply reading for a general understanding may suffice, rendering the potential benefits of reading in print moot. The question becomes, are students willing to give up detailed understanding of the text read in order to have the ease offered by digital texts?

Clearly, the answers to the question of whether it is best to read digitally or in print is neither simple nor straightforward. Evidently, there is still much to be learned about the nature of reading and comprehending when the medium is digital or print, not solely in terms of the cognitive processing that transpires, but also with regard to any motivational, sociocultural, or visual-motor factors that are implicated. Yet, in light of the pervasiveness of multiple mediums in the lives of mature readers, these complexities must be more richly examined and better articulated if the goal of enhancing student learning and academic development is to be fostered.

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Appendix

Excerpt from childhood asthma

Healing the New Childhood Epidemics: Autism, ADHD, Asthma, and Allergies—The Groundbreaking Program for the 4-A Disorders (Bock & Stauth, 2008).

Determining the root cause of asthma was not an easy feat. However, other practitioners continued to dig even more deeply into asthma's root causes. Some of us who were treating asthma almost every day came to believe that there was an even more basic root cause than that of the classic asthma triggers. This more fundamental root cause appeared to be whatever was causing the inflammation.

In the last decade, the medical mainstream began to agree that whatever was causing the inflammation was also the root cause of asthma. Prior to this, the medical field could not come to a conclusion regarding what caused asthma. Once it was agreed upon that whatever was causing the inflammation was also the root cause of asthma, it could be treated better. As a result of this discovery, doctors added a new treatment. In addition to the existing treatment of dilating bronchial tubes, doctors began also putting patients on continuing courses of daily drugs to help prevent asthma episodes from being triggered. Steroids are traditionally used to dilate the bronchial tubes, which treat and help to reduce inflammation in a patient.

Even this approach, however, fails to reach the real root cause of asthma. The root cause of asthma is: the original source of the inflammation.

Therefore, to defeat asthma we must dig all the way to the sources of inflammation. This can be hard to do because one must figure out what is causing the inflammation to begin with. It's much easier to just give patients steroids to decrease their inflammation. One confusing factor in the quest to eliminate the original sources of inflammation is that these sources can also be the direct triggers of asthma. Fungus, for example, can cause infectious inflammation, and then later fungus can act as the direct irritant that triggers an asthma episode. When this happens, patients sometimes remove themselves from the mold that triggered the episode, but they still might have a low-grade fungal infection simmering away

Scoring guide

Main idea

Childhood asthma can be treated by knowing the antecedent triggers of inflammation.

Key Points

- □ It wasn't until the last decade that doctors discovered what causes asthma.
- □ The root cause of asthma is the original source of the inflammation.
- □ There are two standard approaches to treating asthma.
- □ It can be confusing to treat because you need to discover what is triggering it.

Other relevant information

- □ Fungus can be a trigger of inflammation.
- □ Steroids can be used to treat inflammation.
- □ It can be hard to figure out what the triggers are.
- □ Doctors can dilate bronchial tubes to help with asthma.
- □ Drugs can be given to use daily before an asthma episode arises.