Learning from Paper, Learning from Screens:
Impact of Screen Reading and Multitasking Conditions on Reading and Writing among College Students

Kaveri Subrahmanyam, California State University, Los Angeles, CA, USA & Children's Digital Media Center @ Los Angeles, Los Angeles, CA, USA

Minas Michikyan, California State University, Los Angeles, CA, USA & Children's Digital Media Center @ Los Angeles, Los Angeles, CA, USA

Christine Clemmons, Children's Digital Media Center @ Los Angeles, Los Angeles, CA, USA & University of California, Los Angeles, CA, USA

Rogelio Carrillo, California State University, Los Angeles, CA, USA & Children's Digital Media Center @ Los Angeles, Los Angeles, CA, USA

Yalda T. Uhls, Children's Digital Media Center @ Los Angeles, Los Angeles, CA, USA & University of California, Los Angeles, CA, USA

Patricia M. Greenfield, Children's Digital Media Center @ Los Angeles, Los Angeles, CA, USA & University of California, Los Angeles, CA, USA

ABSTRACT

Electronic screens on laptop and tablet computers are being used for reading text, often while multitasking. Two experimental studies with college students explored the effect of medium and opportunities to multitask on reading (Study 1) and report writing (Study 2). In Study 1, participants (N = 120) read an easy and difficult passage on paper, a laptop, or tablet, while either multitasking or not multitasking. Neither multitasking nor medium impacted reading comprehension, but those who multitasked took longer to read both passages, indicating loss of efficiency with multitasking. In Study 2, participants (N = 67) were asked to synthesize source material in multiple texts to write a one-page evidence-based report. Participants read the source texts either on (1) paper, (2) computer screen without Internet or printer access, or (3) computer screen with Internet and printer access (called the "real-world" condition). There were no differences in report quality or efficiency between those whose source materials were paper or computer. However, global report quality was significantly better when participants read source texts on a computer screen without Internet or printer access, compared with when they had Internet and printer access. Active use of paper for note-taking greatly reduced the negative impact of Internet and printer access in the real-world condition. Although participants expressed a preference for accessing information on paper, reading the texts on paper did not make a significant difference in report quality, compared with either of the two computer conditions. Implications for formal and informal learning are discussed.

Keywords: *Electronic Screens, Multitasking, Paper, Reading Comprehension, Reading Time, Report Writing, Tablet Computers*

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INTRODUCTION

Electronic screens such as those found in computers, laptops, tablet computers, and e-readers are increasingly used to read text, and it is important to consider their implications for student learning. Data collected by the Pew Internet and American Project suggest that, as of May 2013, 56% of American adults owned a smartphone (e.g., Android, iPhone) and 34% owned a tablet computer; as of April 2012, 61% owned a laptop and 58% owned a desktop computer (Brenner, 2013; Zickuhr, 2013). In 2010, between 59% and 93% of U.S. college students (community college, undergraduate, and graduate students) reported owning a desktop or a laptop computer (Smith, et al., 2011). Among youth, a 2012 survey of U.S. 12- to 17-year-olds reported that 93% have home computer access, 37% own a smartphone, and 23% have a tablet computer; one in four reported that they are "cell-mostly" Internet users, who use their phone to go online most of the time (Madden & Lenhart, 2013). Moreover, tablets and electronic books are being adopted by students of all ages for access to textbooks and other instructional materials (Hu, 2011; Rockinson-Szapkiw, 2011) and recently, the Los Angeles Unified District approved iPads for every child in the district's schools (Blume, 2013).

Given that electronic screens have become pervasive, it is important to examine how individuals process, comprehend, and utilize digital text compared with text on the traditional medium of paper. This paper describes two studies that examined the relative effectiveness and efficiency of screens versus paper for reading as well as synthesizing information and writing a research-based report under naturalistic conditions. Because so much reading and writing takes place in environments that include access to the Internet or to a cell phone, multitasking while reading or writing on the computer has also come into play. The effects of the resulting distraction on reading (Study 1) and report-writing (Study 2) are also explored in the present research. The results have potentially important implications for both formal and informal learning.

ELECTRONIC SCREENS AS CULTURAL TOOLS

Why would we expect electronic screens or the particular reading medium to affect how learners process text? To answer this question, we turn to Vygotsky's proposal that cognitive development is mediated by the semiotic mechanisms or psychological tools provided by the culture such as language, counting systems, algebra, and writing (Vygotsky, 1978). Sociocultural theorists now recognize that tools such as the paint brush, computers, calendars, and symbol systems also play an important role in knowledge construction during development (John-Steiner & Mahn, 1996). Indeed mass media such as radio, film, and television, were considered to be early electronic tools and have been joined today by digital media such as tablet computers, video and computer games, and the Internet (Greenfield, 1994; Subrahmanyam & Greenfield, 2008). Greenfield (1993) has posited that cognitive socialization is the process by which cultural tools impact processing skills; on this view, different tools utilize and require different processing skills. As a widely used cultural artifact, media are important tools of cognitive socialization (Subrahmanyam & Greenfield, 2008). Different media use different symbol systems – radio uses auditory representations, television uses auditory, iconic, and visual representations, and computer games use auditory, iconic, visual, dynamic, and spatial representations. Consequently, repeated use of a particular media form will help to internalize the medium-specific representational skills that it uses.

Research has shown that different media forms do indeed help to foster and develop different cognitive skills (Subrahmanyam & Greenfield, 2008). For instance, several experimental studies have shown that repeated computer game playing enhances selected at-

tentional, iconic, and spatial representational skills (for recent reviews of these studies see Greenfield, 2009; Subrahmanyam & Greenfield, 2008). Research also suggests that the medium may influence how the information presented is processed. To compare the effect of radio and television, Greenfield and colleagues presented children (grades 1 to 2 and 3 to 4) with a video version and an audio version of children's stories using the identical soundtrack. Hearing the audio version led to better imagination on a story-ending task, whereas viewing the video led to better recall (Greenfield & Beagles-Roos, 1988; Greenfield, Farrar, & Beagles-Roos, 1986). Together, these studies show that electronic cultural tools such as television and computer games can mediate cognitive processing.

As mentioned above, electronic screens such as those found on computers, laptops, and tablet computers are being used more and more by youth and adults to read text, for school (e.g., expository text in textbooks, research papers, websites), as well as for pleasure (e.g., narrative text in novels, magazines, websites) (Pew Research Center, 2012), often when multitasking with media (Junco & Cotten, 2012; Levine, Waite, & Bowman, 2007). Like other cultural tools that have had cognitive impacts, screens may similarly be changing the way people read, and thus it is important to examine whether they impact the efficiency and effectiveness of reading and processing text. In the next sections, we review extant research comparing reading on computer screens versus paper, as well as research on multitasking.

USE OF PAPER VERSUS ELECTRONIC SCREENS FOR READING

First, we consider the extent to which electronic screens are used for reading. Survey data reviewed earlier suggest that significant majorities of U.S. college students and older adults own desktop, laptop, and tablet computers (Brenner, 2013; Smith et al., 2011; Zickuhr, 2013). As of January 2012, 29% of U.S. adults 18 and older reported that they owned at least one device for reading electronic text such as a tablet or e-book reader (e.g., Kindle or Nook) (Rainie, Zickuhr, Purcell, Madden, & Brenner, 2012). These devices can be used to read digital documents in a variety of formats – including standard websites (HTML format) and documents created using proprietary file formats (e.g., DOCX or PDF). Some of these file formats (e.g., HTML, PDF) can be read on a variety of electronic devices (e.g., any laptop or tablet computer), whereas others (e.g., AZW) can only be read on specific devices such as e-readers (e.g., AZW can only be read on Kindles or on iPads using the Kindle app) (Wexelbaum & Parault, 2011). In this paper, we focus more broadly on digital text read on electronic screens regardless of the particular software format (e-book versus PDF document) in which the text may be read.

As ownership of electronic devices has increased, there has been a concomitant shift in reading from paper to electronic platforms. In a 2012 Pew survey, 23% of U.S residents 16 and older reported reading an e-book compared to 16% 12 months prior; in contrast, there was a decrease in the percentage who reported reading printed books from 72% to 67% during the same period (Rainie & Duggan, 2012). On another 2012 Pew survey of U.S. respondents, 51% reported that they "enjoy reading a lot," but a "declining proportion gets news or reads other material on paper on a typical day." In fact, only 23% reported reading a print newspaper compared to 41% in the previous decade. In the same survey, between 44% to 55% of regular readers of three major newspapers [New York Times (55%), USA Today (48%), and Wall Street Journal (44%)] reported that they mostly read the paper on a digital device. Among those who reported reading a magazine and book the previous day, there was a similar shift from paper to tablets, digital books, and other devices (9% for magazines and 20% for book readers) (Pew Research Center, 2012).

Data concerning the use of e-books among students is more mixed. For instance book

publisher Springer surveyed respondents at five educational institutions in Europe, U.S., and Asia and found that 73% had used e-books, with most accessing e-books on a weekly/monthly basis. Interestingly, respondents in this survey reported that that they mostly used e-books for research as well as study; reference works, conference proceedings, and textbooks were the most frequently downloaded e-books (van der Velde & Ernst, 2009). Thus it may be that digital sources are being used mostly for news and research purposes (Pew Research Center, 2012; van der Velde & Ernst, 2009; Wexelbaum & Parault, 2011). At the same time, reading on paper is still common place; Liu and Stork (2000) have suggested that although more people are reading digital text, they still value paper formats.

READING ON PAPER VERSUS SCREEN

Research also suggests that people use very different strategies when reading text on screens versus paper formats. In a self-report survey of 113 people, Liu found that, while engaged in screen-based reading, more time was spent "on browsing and scanning, keyword spotting, one-time reading, non-linear reading, and reading more selectively, while less time is spent on in-depth reading, and concentrated reading" (Liu, 2005, p. 700). Respondents also reported that they had noticed a decrease in sustained attention while engaged in screen-based reading (Liu, 2005). Similarly a large survey of 16,000 students and faculty members in the U.K. revealed that respondents did not spend a sustained amount of time on e-book or journal articles and only spent about four minutes at an e-book site. Instead, they skimmed and moved from source to source, using techniques such as "horizontal information seeking" and "power browsing" (Jamali, Nicholas, & Rowlands, 2009). Additionally, annotating and highlighting, which are commonly used when reading printed sources, had not yet been widely adopted for reading electronic sources at the time of the study (Liu, 2005). In fact, based on an increase in the paper used by printers, Liu and Stork speculate that many people prefer to print and annotate/underline articles as they read and also do not like reading long documents on screen (Liu & Stork, 2000).

EFFECTS OF READING ON PAPER VERSUS SCREENS

Although there has been renewed attention to screen-based reading since the arrival of the Internet and portable reading devices, researchers have actually been conducting experiments to compare reading on paper versus screens since the early days of video display terminals (VDTs) (for reviews of this work, see Dillon, Mcknight, & Richardson, 1988; Dillon, 1992; Noyes & Garland, 2008). In the majority of studies, participants were asked to read a passage, either on paper or on the computer screen, and their comprehension of the text was assessed, typically using multiple choice questions. Because this research (Kak, 1981; Muter, Latrémouille, Treurniet, & Beam, 1982; Oborne & Holton, 1988) focused on the first generation of video screens that are very different from digital screens found on laptops and tablet computers, we examine them only briefly. Based on a review of this early work, Dillon concluded that although there was no difference between paper and VDTs with regard to reading comprehension, reading speed was slower on VDTs. There was some indication that reading accuracy, defined as the number of errors identified in a proof reading exercise, may be reduced on VDTs for cognitively demanding tasks (Dillon, 1992). Subsequent research comparing reading speed and comprehension on paper and VDTs has found both faster reading speed on paper (Mayes, Sims, & Koonce, 2001) as well as no difference between the two (Noyes & Garland, 2003). Based on a review of this research, Noyes and Garland have argued that when comparing paper and screen-based

modes of presentation, one should ensure that computer-based and paper-based tasks are equivalent and use multiple measures of reading performance (Noyes & Garland, 2008).

Recent research comparing reading on paper versus the current generation of computer screens has also produced inconsistent findings. In a Norwegian study, 10th graders read two texts either in print or as a PDF document on 15" LCD monitors (operating at 60 Hz, with a resolution of 1280 X 1024 pixels). Results suggest that those who read the text on paper did significantly better on a test of reading comprehension compared with those who read it on the screen (Mangen, Walgermo, & Brønnick, 2013). In contrast, in a study of Austrian medical professionals (Holzinger et al., 2011), where participants read authentic medical reports and documents on both screens and paper, no difference was found in reading performance (comprehension, speed, and accuracy) as a function of reading medium.

One reason for these differing findings may be that the studies did not manipulate task difficulty. Manipulating task difficulty is important since earlier research comparing paper and screens found a limited advantage on reading accuracy for paper during difficult tasks (Dillon, 1992). The study by Mangen and colleagues (2013) used texts developed for reading research and student assessment that the school-age participants might have found more difficult, whereas Holzinger et al.'s study (2011) asked medical professionals to read medical reports, and this subject matter might have made the reading task easier. It is possible that the reading medium may not have an impact when reading familiar and easy text, but may play a role in cognitively demanding tasks such as reading difficult texts. Given that people report lower attention and less in-depth reading (Liu, 2005), as well as reading strategies such as skimming and power browsing (Jamali et al., 2009) when reading text on screens, reading comprehension may be disrupted when reading difficult text on screens.

MULTITASKING WHEN READING ON SCREENS

At the same time, the technology landscape has changed, and screen-based reading now occurs on desktop computers, as well as on portable laptops and tablet computers, smart phones, and e-book readers. Many of these devices have enhanced resolution and graphics (e.g., the retina display of the iPad), which may impact reading speed. The devices also provide a variety of tools - for manipulating the text, making notes, and quickly checking the definition and meaning of terms - features that may help with comprehending the text. Nevertheless, research that compares reading on screens versus paper has not systematically included these newer tablet computers. Additionally, tablets and laptops devices are enabled with wireless and it is common for users to be multitasking (e.g., surfing the web, chatting on messaging clients, or text messaging on smartphones) while reading on screens (Levine, Waite, & Bowman, 2012; Tran, Subrahmanyam, & Carrillo, 2013). Indeed, among college students, computer and Internet use frequently occurs in multitasking environments, wherein the individual rapidly switches between multiple windows (involving different applications or even different windows within the same application) or simultaneously uses multiple media (e.g., computer, music, and television) (Junco & Cotten, 2012; Levine et al., 2007). Recent data suggest that, when using media, college students multitask with three (Ophir, Nass, & Wagner, 2009) or even four devices/activities simultaneously (Tran et al., 2013). Researchers have noted that, although the term multitasking is used to refer to such simultaneous use, it is not true simultaneous multitasking, but instead entails rapid shifting or switching between different tasks or media (Kirschner & Karpinski, 2010; Tran et al., 2013).

Drawing on cognitive load theory (Sweller, 1994) and findings that learning may be disrupted when cognitive load exceeds a learner's working memory capacity (Paas, Renkl, &

Sweller, 2004; Schnotz & Kürschner, 2007), Tran and colleagues have suggested that the constant switching of attention entailed while reading and multitasking may increase cognitive load and thus disrupt reading comprehension (Tran et al., 2013; see also a recent review of research on the effects of media multitasking on driving, walking, work, and academic performance by Levine et al., 2012). Experimental studies on the cognitive costs versus benefits of online multitasking for comprehension typically require participants to read a passage either under simulated conditions of multitasking (e.g., reading and instant messaging simultaneously) or no multitasking (e.g., reading and instant messaging sequentially) (Bowman, Levine, Waite, & Gendron, 2010; Fox, Rosen, & Crawford, 2009; Tran et al., 2013). The results have been equivocal and simulations of multitasking have yielded no effects (Bowman et al., 2010; Fox et al., 2009), some benefits when reading easy text (Tran et al., 2013), and negative effects (Hembrooke & Gay, 2003) on memory.

THE PRESENT RESEARCH

Reading on screens is becoming more prevalent both in and out of classroom settings. Although earlier research comparing reading on screens and paper has shown no consistent advantage for either medium, nonetheless given the widespread adoption of e-books and tablet computers by schools (Blume, 2013; Hu, 2011), it is important to revisit this question. This is especially so as screen-based devices have changed – they have become smaller and more portable with enhanced resolution and graphics and better note-taking and comprehension-aiding tools. At the same time, a lot of reading, whether on paper or screens, occurs while the learner is also switching between windows (e.g., multiple documents), websites, or even devices (e.g., text messaging). Despite indications that such multitasking is rampant (Junco & Cotten, 2012; Ophir et al., 2009; Tran et al., 2013), research has not examined the extent to which students actually engage in it when reading on paper versus screens for different purposes and the consequences of such shifting attention. Thus, any examination of the effect of the reading medium must take into account the potential role of multitasking, especially as it has become an integral part of reading on screens. The present research addresses these gaps and examines the effect of the reading medium (paper vs. screens) and multitasking on reading performance (Study 1) and the ability to synthesize and use written materials to prepare a evidence-based report that requires critical thinking (Study 2).

Study 1: Effects of Medium and Multitasking on Reading

In order to compare reading on paper with newer screen modes, we asked participants to read passages on paper, laptop, or a tablet while either having the opportunity to multitask or not. Because any effect of the reading medium and multitasking might depend on the nature of the text, we used both an easy narrative passage and a more difficult expository passage. All participants were given medium-specific tools to take notes or to highlight. Those in the screen conditions were given a brief demonstration on how to make notes or highlight passages. In order to create an ecologically valid simulation of multitasking, we instructed participants in the multitasking condition to read and multitask (online, on their cell phones, and even playing games) as they typically did when reading text for school or pleasure.

To ensure task equivalency when reading the text in the different conditions, we standardized how the material was presented on paper and screen. The text was presented in PDF format for the screen conditions and a print-out of this document was used for the paper condition. The document used two-column texts and single spacing to provide an organized and visually interesting display (Grabinger, 1993). To control for legibility and preferences in text presentation, we used the standard 12-point Times

New Roman font for the passages (Darroch, Goodman, Brewster, & Gray, 2005; Kingery & Furuta, 1997). Following the recommendation of Noyes and Garland (2008), we measured two different aspects of reading performance - total reading/study time and reading comprehension. Because verbal working memory as measured by the Reading Span Test (RST) is correlated with reading comprehension (Daneman & Carpenter, 1980), we used a computerized version of the RST (van den Noort, Bosch, Haverkort, & Hugdahl, 2008) to obtain a measure of verbal working memory that was used as a covariate in all analyses.

Hypotheses

Since this is one of the first studies to compare paper with laptop and tablet computers in the context of multitasking, our hypotheses are more exploratory in nature. Even though earlier research found slower reading speed on screens (Dillon, 1992; Mayes et al., 2001), given the improvement in laptop and tablet technology, we did not expect any difference in the total reading/study time as a function of reading medium. Although prior research on the effect of the medium on reading comprehension has yielded contradictory results (Dillon, 1992; Holzinger et al., 2011; Mangen et al., 2013; Noyes & Garland, 2003), those studies did not manipulate text difficulty. It is possible that the reading medium does not impact comprehension when reading text with familiar language structures and easy content, but may do so when reading difficult text on screens. Thus, we predicted no difference in reading comprehension as a function of the medium when reading the easy passage; however, because people often skim, browse, and report lower attention when reading on screens (Jamali et al., 2009; Liu, 2005), we predicted that reading performance would be worse when reading the difficult passage on the laptop and tablet. The research to date on the effects of online multitasking on reading comprehension has been equivocal; however given that repeated switches in attention might tax a learners' working memory (Tran et al., 2013), we predicted that multitasking would increase the total reading time and disrupt reading comprehension, with greater effects when reading the difficult passage on screens.

Method

- **Participants:** Participants included 120 college students (60 women, 60 men, M_{age} = 20.93 years, age range: 18-30 years), who were recruited from the psychology subject pool at a large urban university in Southern California. They were in a variety of majors and were enrolled in an introductory psychology course and life span course for General Education credit. The ethnic distribution was as follows: 26% Asian American, 4% African American, 60% Latino/Hispanic, 6% European American, and 4% other ethnic groups. The mean grade-point-average (GPA) of the participants was 2.98 and 63% reported that they could speak two languages;
- **Apparatus:** For the laptop condition, we used a Hewlett-Packard (HP) Envy Pro Ultrabook PC with a 14-inch LED-backlit HD BrightView screen and 1366 x 768 resolution. For the tablet condition, we used a second-generation full-sized iPad, with a LED-backlit glossy widescreen (1024 x 768 resolution at 132 pixels per inch), multi-touch display with IPS technology. The reading comprehension task was administered on a Dell Optiplex 960, Intel Core 2 Duo processor, and 1908FB UltraSharp Black 19-inch flat panel monitor with 1280x1024 screen resolution;
- **Experimental tasks:** The experimental tasks consisted of a reading task and a reading comprehension task:
  - **Reading task:** The reading task consisted of an easy and a difficult passage from SAT-released exams. The easy passage contained narrative text and was an excerpt from a memoir, in which the author reminisced about childhood trips to the library and her love for reading. The text contained

843 words and was at an 8th-grade readability level. The difficult passage contained expository text and was a critique of dominant social theories about the effect of television on humans. It contained 735 words and was at a college readability level. For each passage, we assessed reading time and comprehension;

- **Reading comprehension task:** The reading comprehension task assessed participants' comprehension of the material presented in the two passages. For each passage, there were 15 multiple-choice comprehension questions, 12 of which were from the SAT- released exam. Three questions were created by us in accordance with criteria used in prior research (Ackerman & Goldsmith, 2011) and were designed to assess both surface-level as well as deep-level comprehension of the passage text. The reading comprehension task was administered using the SuperLab program;

- **Measures:** We used the following measures:
  - **Reading Span Test (RST):** To obtain a measure of verbal working memory, which is the short-term memory for words, we used the computerized English version of the Reading Span Test (van den Noort et al., 2008). The RST contains a total of 100 unrelated sentences written in active voice and ranging in length from 12 to 17 words. The sentences were presented in five different series of 20 sentences with each series consisting of two, three, four, five, or six sentences. Participants read each sentence aloud as fast as they could and were told to read for content. When finished with a sentence they pressed the space bar to proceed to the next one. Each sentence remained on the screen for 6.5 seconds before it was automatically switched. When all the sentences of a series were read, participants were prompted to recall in any order the last word of every sentence in that series;
  - **Multitasking Profile:** The five-item Multitasking Profile (Tran et al., 2013) used a 5-point Likert scale (1=*strongly disagree*, 5=*strongly agree*) to assess the degree to which participants endorsed multitasking and considered themselves to be multitaskers. A sample item included: "I consider myself someone who does more than one thing at a time." Cronbach's alpha was .86;
  - **Media-Use Questionnaire:** We developed a Media-Use Questionnaire to assess participants' habitual media use, multitasking beliefs and frequency, intensity of technology use, as well as their frequency of reading on paper versus screens;
  - **Demographics Questionnaire:** We developed a Demographics Questionnaire to obtain demographic information about participants including their age, ethnicity, class standing in college, and GPA;
- **Design:** We used a 3 (medium) X 2 (multitasking) X 2 (passage) mixed design with medium (paper, laptop, and tablet) and multitasking (multitasking, no-multitasking) as between-subjects factors and passage (easy, difficult) as a within-subjects factor. Twenty participants were randomly assigned to the six conditions resulting in a total of 120 participants; the order of presentation of the passage (easy and difficult) was counterbalanced so that half the participants in each condition read the easy passage first and half read the difficult passage first;
- **Procedure.** The testing room was arranged to look like a college dorm room with a futon, center table, bookshelves, and a laptop desk. After participants completed the informed consent process, they read the

passages and then completed the reading comprehension task. Participants were told to take as much time as they wanted and read as many times as they needed until they felt ready to answer the reading comprehension questions. They were allowed to use medium-appropriate tools to take notes and highlight texts. For participants who read the text on paper, this included pen, pencils, and highlighters; for those in the laptop and tablet conditions, the researcher briefly demonstrated how to use electronic highlighting and comment-writing tools specific to the medium. Participants who agreed were videotaped while they were reading the passages.

Participants in the multitasking condition were told that they could access the Internet and use their cell phone when reading the passage -- in other words, they could do what they typically did when reading. Participants who read the passage on paper or laptop multitasked with a laptop and cell phone; those in the tablet condition multitasked on the tablet and cell phone. Participants in the no-multitasking condition were asked to not access the Internet or use their cell phone while reading the passages.

The SuperLab program was used to measure participants' total reading/study time that a participant felt he/she needed to complete the reading comprehension task. It included the time spent reading and re-reading; for participants in the multitasking condition, it also included time spent switching between the passage and their cell phones/Internet. After participants read each passage, they completed the reading comprehension task, which was administered by the SuperLab program, which also recorded the responses. Then, participants completed the Reading Span Test (RST) administered using the E-prime program, and the Media Use and Demographics questionnaires on the survey hosting website, www.surveymonkey.com:

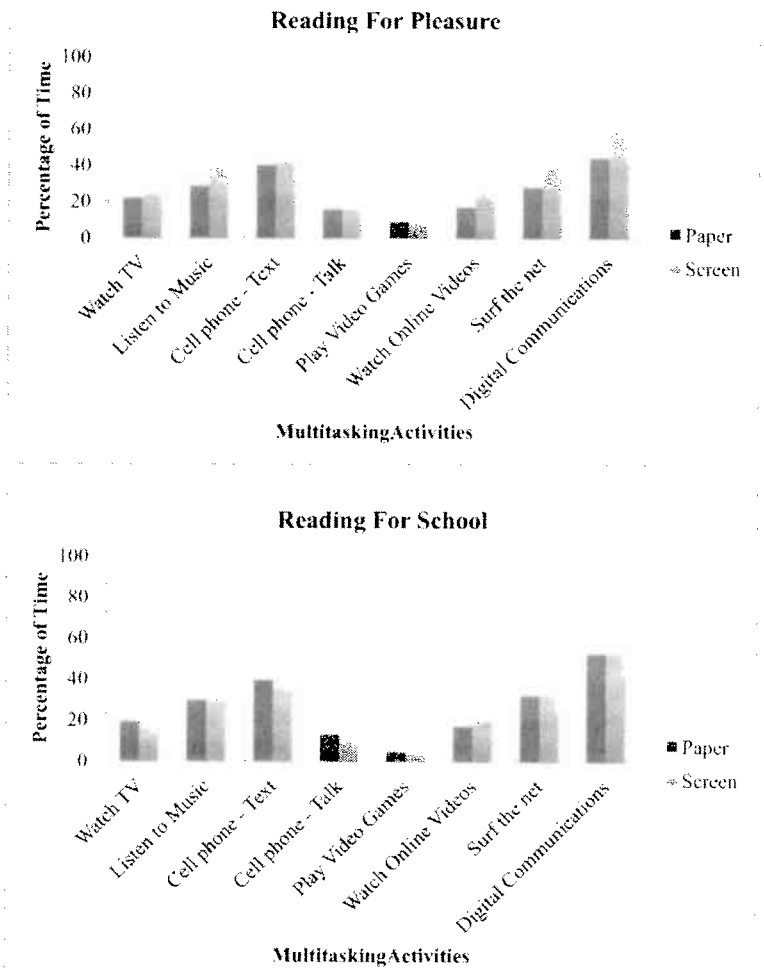
- **Data Analysis:** For the reading task, the scores entered into the analysis included the total reading/study time in minutes, and the proportion of correct responses on the reading comprehension task. Two sets of analyses were done. First, we analyzed the data from the paper, tablet, and laptop conditions separately; then we collapsed the data from the tablet and laptop conditions to create a screen condition and compared the paper and screen conditions. We used a multivariate analysis of covariance, with participants' score on the RST as a covariate; significant effects were then analyzed using univariate analyses of variance followed by pair-wise comparisons. The video recordings made when reading the passage were examined to determine whether a participant used medium- appropriate note-taking tools and also the number of times he/she switched between the reading task, and other applications/devices.

Results

All participants reported having a personal computer/laptop; 9% reported having a specialized e-book reader such as Kindle or Nook and 18% reported that they had a tablet computer with the majority reporting that it was an iPad. Forty percent of participants reported that they read paper-based print sources very often or always and 43% reported that they did so sometimes; 60% reported that they read electronic sources of print very often or always and 31% said they did so sometimes. Thirty-eight percent agreed or strongly agreed that they enjoyed reading and 23% agreed or strongly agreed that they read for pleasure every day.

Overall our participants considered themselves to be moderate multitaskers ($M = 3.41$ on a scale ranging from 1 to 5, $SD = .79$). Figure 1 shows the percent of time that participants reported that they typically multitasked while reading on paper and screens for pleasure and school respectively. Paired-sample t-tests indicated that when reading for pleasure, participants reported multitasking more when reading on screens than on paper, with the following media-based activities: listening to music, viewing online videos, surfing the

Figure 1. Percent of time on different multitasking activities while reading for pleasure (top panel) and for school (bottom panel) as a function of reading medium (paper vs. screen)



Internet, and digital communications (writing emails, visiting social networking sites) (*p*s ranged from .047 to .000) (see top, Figure 1). When reading for school, they reported more texting and talking on cell phones while reading on paper and more watching of online videos while reading on screens (*p*s ranged from .030 to .043) (see bottom, Figure 1).

To check for order effects (easy/difficult passage vs. difficult/easy passage), we did two separate mixed analyses of covariance [2 (passage) X 3 (medium) X 2 (multitasking) X 2 (order)] on each of the two dependent variables (DVs) – reading time and proportion correct. In each of these analyses, passage was a within-subjects factor, and medium, multitasking, and order were between-subjects factors, with the RST score as a covariate. Except for one significant interaction of medium, multitasking, and order for reading time on the difficult passage ($p = .040$), we found no consistent main effect for order or interactions of any factor with order (all *p*s > .05). Thus we concluded that the one significant effect was produced by chance and

the data were combined across orders for all subsequent analyses.

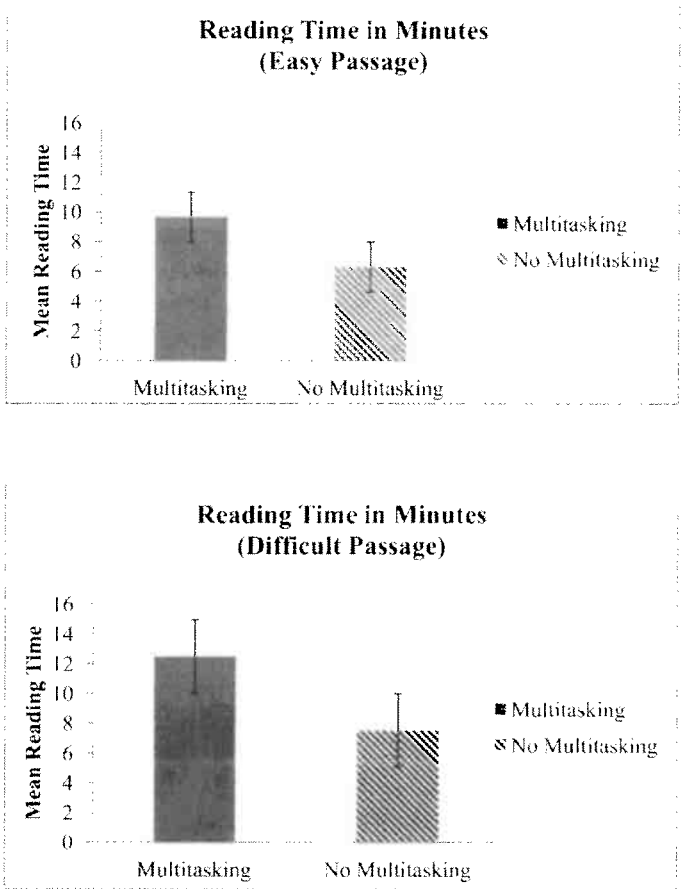
To determine the relative roles of the medium and multitasking on reading efficiency and effectiveness, a 2 X 3 between-subjects multivariate analysis of covariance (MANCOVA) was performed on the following four dependent variables: proportion correct (easy passage), proportion correct (difficult passage), reading time (easy passage), and reading time (difficult passage). Adjustment was made for one covariate – score on the RST (verbal working memory). Independent variables were medium (paper, laptop and tablet) and multitasking (yes, no). Order of entry of IVs was medium and then multitasking. Results of the evaluation of key assumptions were judged to be mostly adequately satisfied. The only exception was Box's M test, which was significant ($p = .000$). MANOVA is robust against Type I error when cell sizes are equal and power is good. Given that these conditions were satisfied, it was determined that the results of the MANCOVA would be robust against the possibility of Type I error; as a precaution, a more stringent test such as Pillai's Trace was used to judge significance of the results with p set at .01.

Controlling for verbal working memory (RST score), the two-way MANCOVA revealed a significant multivariate main effect for multitasking, [Pillai's Trace = .28, F (6, 108) = 7.09, p = .000, partial eta squared = .283, power = 1.00]. Given the significance of multitasking in the overall test, univariate main effects were examined for multitasking. Using Bonferroni's correction, alpha was set at .01. Significant univariate main effects for multitasking were obtained only for time spent reading the easy passage [F (1, 113) = 24.30, p = .000, partial eta square =.177, power = .98] and time spent reading the difficult passage [F(1, 113) =27.45, p =.000, partial eta square = .195, power = .99]. Pair-wise comparisons suggested that reading time was greater in the multitasking conditions for both the easy and the difficult passage (p = .000) (see Figure 2). There was no effect of medium on reading comprehension.

Next, to clarify the effect of multitasking, we analyzed the data from the participants in the multitasking condition (N = 60). Among those participants who agreed to be videotaped (N = 42), 45% used their cell phones, 79% used the Internet while reading the passages, and 86% did both. Cell phone and Internet use were further coded into four "frequency of switching" categories: no, low (one time), medium (two or three times), and high (four or more). The proportion correct responses for the easy and difficult passage were analyzed using two separate ANOVAs with the number of cell phone and Internet switches as between-subjects factors. No significant differences were found. A similar analysis for reading time yielded a significant effect of cell phone switches for the easy passage (F (36) = 4.49, p = .009, partial eta squared = .272) and a significant effect of Internet switches for the difficult passage (F (38) = 3.34, p =.029, partial eta squared = .209). Post-hoc Tukey HSD tests revealed that the participants who switched to their cell phone four or more times also took longer to read the easy passage compared to those who did not at all switch to their cell phone (M = 17.17 minutes, SD = 4.72 vs. M = 9.13 minutes, SD = 4.63, p = .006). Similarly, those who switched to the Internet four or more times took longer to read the difficult passage compared to those who did not at all switch to the Internet (M = 16.89 minutes, SD = 6.80 vs. M = 8.86 minutes, SD = 4.33, p = .016).

Even though the reading medium did not have a significant impact on reading comprehension, we conducted follow-up analyses to see whether the medium may have subtle influences on how people read. Examination of the videotapes indicated that when reading the easy passage, note taking and highlighting was more frequent when reading on paper with the following breakdown as a function of medium: 35% (paper), 10% (tablet), and 15% (laptop). For the difficult passage, the percentages were as follows: 43% (paper), 28% (tablet), and 20% (laptop). Separate ANOVAs on the proportion correct for each medium and passage with note-

Figure 2. Mean reading time as a function of multitasking for the easy (top panel) and difficult passage (bottom panel)

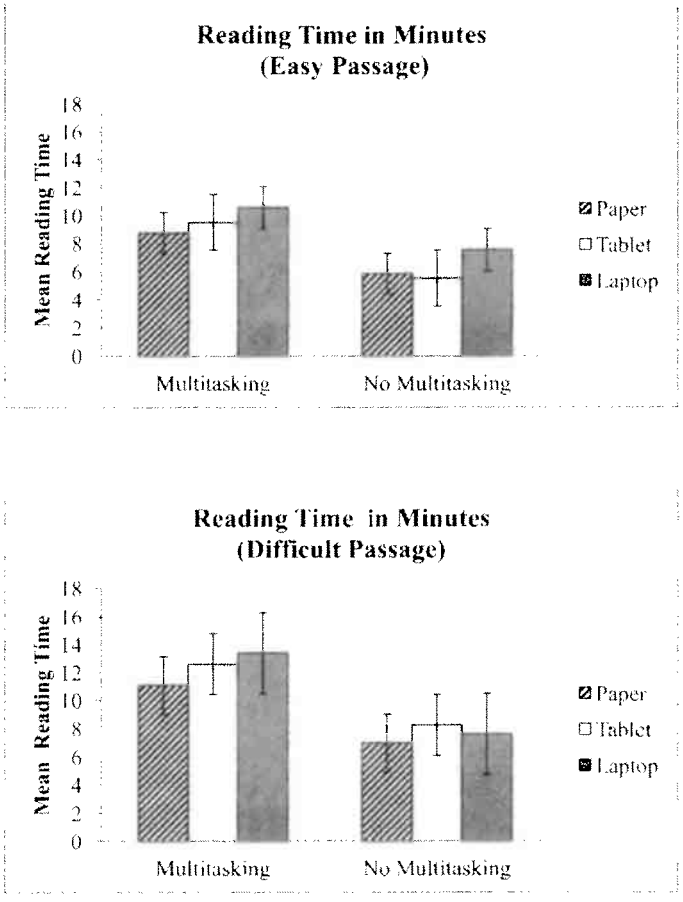


taking and highlighting (no, yes) as a between-subjects factor yielded no significant effects.

Next, we examined the passage-reading-time data as a function of medium and multitasking. We found a trend, though not significant, for lower time while reading on paper, compared to tablet and laptop especially when participants were multitasking [see top panel of Figure 3 for the easy passage and bottom panel for the difficult passage]. The trend for reduced reading time while reading on paper in the multitasking condition could be due to two reasons: First, paper might simply be more effective in suppressing multitasking. Second, multitasking may be less disruptive when a user reads text on one medium and multitasks using a different medium or external device. Since multitasking while reading on paper necessarily involves an external device, this might have contributed to the trend toward reduced reading time with paper.

To explore these alternative possibilities, we examined the percentages of participants who multitasked and the extent of their multitasking (low, medium, and high; for ease of presentation the no and low levels of multitasking were collapsed into one group) in the paper, laptop, and tablet conditions respectively (see Figures 4a, b, and c). The figures show that a majority of the participants in the paper con-

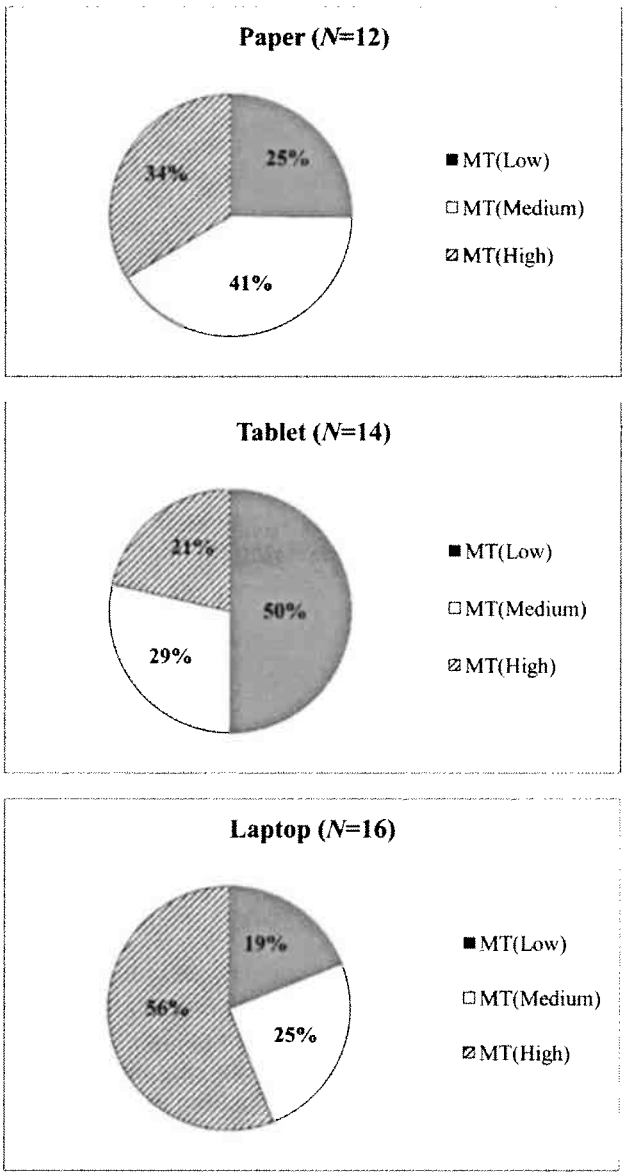
Figure 3. Mean reading time as a function of medium and multitasking for the easy (top panel) and difficult passage (bottom panel)



dition multitasked while reading text; in fact, more participants multitasked while reading on paper compared to the tablet. From Figures 4a, b, c, and Figure 1, which shows the extent to which participants reported that they multitasked typically, it appears that although levels of multitasking are lower when reading on paper, they are not suppressed completely. Instead, with regard to reading time, it may simply be less disruptive if one multitasks on a medium/device that is separate from the reading medium.

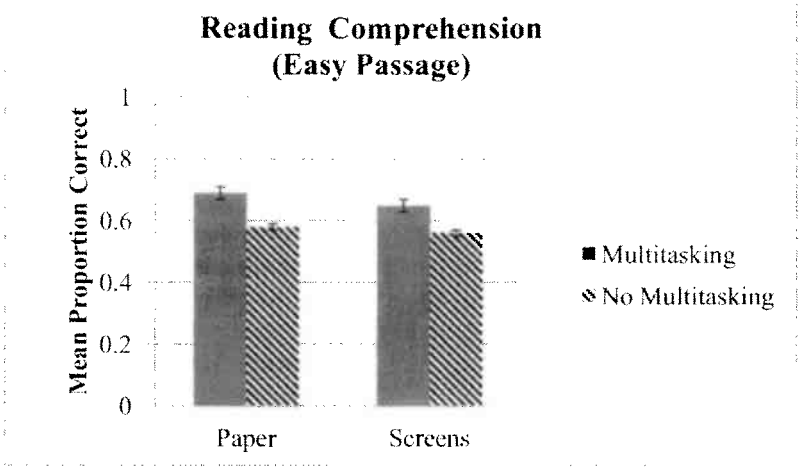
Finally, we analyzed the data from the paper and screen (laptop and tablet) condition separately for each passage. A multivariate analysis of covariance (MANCOVA) on the two DVs (reading time, and proportion correct) for the easy passage with medium (paper and screens) and multitasking (present and absent) as between subjects factors and the RST score as the covariate yielded multivariate effects for multitasking [Pillai's Trace = .18, $F(3, 113) = 8.34$, $p = .000$, partial eta squared = .181, power = .99]. Univariate analysis revealed a significant effect of multitasking for reading time [$F(1, 119) = 19.99$, $p = .000$, partial eta squared = 0.148] and an interaction of multitasking and medium for proportion correct [$F(1, 119) = 4.23$, $p = .042$, partial eta squared = .035]. For reading time, examination of means suggested that participants in the multitasking condition

Figure 4. Percentage of participants who multitasked when reading the text on paper (top panel), tablet (middle panel), and laptop (bottom panel)



spent more time reading the easy passage (M = 9.43 minutes) than those in the no-multitasking condition (M = 6.21) (see top, Figure 2). For reading comprehension, examination of means suggested that among participants who read the easy text on paper, and were in the multitasking condition showed a greater mean proportion correct (M = 0.70) compared to those who were in the no-multitasking condition (M = 0.58) (see Figure 5). This difference was not significant for participants who read the text on a screen. A similar MANCOVA on the two DVs (reading

Figure 5. Proportion of correct responses for the easy passage as a function of medium and multitasking



time and proportion correct) for the difficult passage yielded multivariate effects for multitasking only [Pillai's Trace = .18, F (3, 113) = 8.17, p = .000, partial eta squared = .178, power = .99]. As before, univariate analysis confirmed that multitasking impacted reading time [F (1, 119) = 23.64, p = .000, partial eta squared = .171] and that participants in the multitasking condition (M = 12.07 minutes) took longer to read the difficult passage compared to those in the no-multitasking condition (M = 7.48 minutes) (see bottom, Figure 2).

Discussion

Our results indicate a robust effect of multitasking, which significantly increased reading/study time, even for short texts, regardless of reading medium and type of passage. There was some indication that participants who switched more often to their cell phone or the Internet took longer to read the passage; however we found no evidence that frequency of multitasking switches impacted reading comprehension. Our results also suggest that multitasking may be less disruptive when reading on paper – recall that those who read the easy passage on paper and multitasked scored higher on comprehension than those read the easy passage on paper and did not multitask. In contrast, there was no effect of medium, we found no significant difference between paper, tablet, and laptop for reading time or comprehension. Similarly we also found that medium-specific reading strategies such as note-taking or highlighting had no impact on reading comprehension.

Study 2: Integrating Information from Multiple Sources into an Evidence-Based Report

Study 2 investigated whether the medium in which source material (paper, computer, or computer with Internet and printer) is presented affects performance on a more complex task - writing an evidence-based report that required critical thinking. A critical thinking task is one that requires analyzing and evaluating information from multiple sources in order to compare and contrast ideas and communicate this information to others (Paul, Willsen, & Binker, 1993). Moreover, critical thinking has been highlighted as an essential skill for 21st century academic and workplace competencies (Ananiadou & Claro, 2009). Thus, our focus centered on a writing task that would incorporate aspects of critical thinking for the "real world." For this purpose, we selected a current topic, attention-deficit

hyperactivity disorder (ADHD), and asked participants to examine several different points of view utilizing a variety of texts (Bråten, & Strømsø, 2006). Participants then had to use these texts to synthesize evidence in favor of a point of view in a persuasive, evidence-based essay report. Unlike Study 1, we chose to use a computer rather than a tablet. The reasons were: (1) screen size and software limitations of the tablet make it inadequate for viewing longer documents or multiple documents at the same time (the source materials); (2) a tablet is not very effective for using a word-processing application while viewing documents, as required for our research and report-writing task.

Method

- **Participants:** Participants included 67 college students (51 women, 16 men) from two universities in Southern California. They were awarded course credit to participate. The grade breakdown of the participants included 11 freshmen, 12 sophomores, 15 juniors, 24 seniors, and five post-baccalaureates. The self-reported mean GPA of participants was 3.1. Twelve participants learned English after the age of ten;
- **Apparatus:** The testing room was equipped with a Lenovo *ideacentre,* Intel Core i3 processor desktop computer with a Samsung SA300, 21-inch monitor with 1920 x 1080 screen resolution. The platform was Microsoft's Windows 7. For the computer-with-Internet-and-printer condition, participants had access to the Internet and a Hewlett Packard Office Jet Pro printer. For all three conditions, reports were typed on the computer using Microsoft Word 2010. A Logitech QuickCam Orbit/Sphere AF web cam was used to record each testing session. The free software *Noldus keystroke tracker lite* was used to record keystrokes and Internet usage. For 17 participants the keystroke tracker did not initiate. In these instances, we used a forensic method of data recovery that relied on two programs, Pointstone Software's Index.dat Viewer, and Systenance Software's Index.dat Analyzer 2.5, to recover Internet usage data;
- **Experimental task:** To answer our research question we developed a scenario in which participants were told to assume that they were working in an office where their employer, who has a child diagnosed with ADHD, desired their informed opinion on the best treatment option for this condition. We provided the participant with a series of articles on this controversial topic that not only described the condition but also offered varying opinions on the treatments available. The requested output was a one-page report, which not only outlined the participant's decision, but offered support from their research, using the provided articles. In the case of the computer with Internet and printer condition, the participants were free to do additional research on the Internet;
- **Source materials:** These were seven texts that were excerpts or articles from newspapers, journals, and a textbook. Each text presented a different aspect of ADHD and the surrounding controversy, mainly concerning treatment. For instance, a textbook excerpt described the diagnosis/symptoms and treatment of ADHD in neutral terms without taking an explicit position regarding the controversy surrounding ADHD. Another text was a newspaper article presenting an interview with a physiologist, arguing for the importance of early and lifelong medication. There was a study of the treatment of ADHD taken from a research magazine, with this text presenting arguments against the increased use of medication for ADHD. The remaining articles were of the same varied nature. Depending on the condition, the articles were either available to participants printed out on paper and placed in a manila folder, or presented with generic labels in a digital folder on the desktop of the computer in PDF format. For consistency, we placed the

articles in the paper condition in the same order as those in the computer desktop. All participants were informed of the nature of the articles (some long, some short, news articles, textbook excerpts, etc.) and they were advised to look over all of their materials as there was no particular order to the presentation of articles;

- **Measures:** We used the following measures:
  - **Efficiency:** Our measure of efficiency was the time it took to finish writing the essay. In order to measure time, we used the video recording of the session, starting from the time (rounded to the nearest minute) at which the researcher left the room, just after instructions, to the time at which the participant got up to inform the researcher that he or she had completed the task;
  - **Quality:** To assess quality of output, each essay was graded by two raters using two measures, a rubric and global grade. In the manner used for the writing section of the GREs, a national test for entering graduate students, the graders graded all papers using both measures and an average of the two grades was computed for purpose of the statistical analyses. The rubric was adapted from the California State Critical thinking rubric (Foundation for Critical Thinking, n.d.). Six categories were considered and were assigned a binary score of 0 (not present) or 1 (present). The categories were as follows: 1) Did they define the problem and give an opinion?; 2) Did they offer support for their opinion?; 3) Did they offer a different point of view in a balanced manner?; 4) Did they use more than one source?; 5) Were the references and citations completed as directed?; 6) Was the length greater than one half page? The grades for this measure from the two graders were strongly correlated ($r = .826$, $p = .000$). In addition to the rubric, the graders developed a global grade, informed by the work on the rubric for each report. This score was an implicit measure of quality, meant to reflect real world communication. The guidelines for this measure were to grade the essay with a score from 1 to 10, with 10 being a perfect score that indicated the author successfully communicated an informed and well thought-out opinion. The grades on the global measure from the two graders were strongly correlated ($r = .925$, $p = .000$);
  - **Demographic questionnaire:** We utilized questions about each participant's current year of study (freshman, sophomore, etc.), gender, GPA, number of years speaking English, and parental education level;
  - **Funnel exit interview script:** We developed a funnel exit interview script that contained questions about participants' preferences for using media to complete tasks in general. The two questions that were used in the present analysis are the following: Did they prefer working on the computer for source materials in a task such as the one they were presented or would they prefer printed materials? If the task were studying rather than report writing, do they prefer working on the computer or with printed materials?
- **Design:** Participants were randomly assigned to one of three conditions: paper only, computer only, and what we termed the "real world" condition. In the isolated-medium conditions (paper or computer), participants were provided with the seven texts – either in PDF format on the computer or printed out on paper. In the "real world" condition they were presented seven texts in PDF format on the computer and were also told they could use the Internet and the printer if they so desired. Using the Internet was conceived as a potential distraction. Using the printer was conceived

as an active way to obtain printed materials and also a measure of the desire to have printed materials to complete the task. In all three conditions, participants could also take notes if they wished;

- **Procedure:** Upon arrival, each participant was given a consent form to sign. Next, the participant was taken to a private room with a large desk, computer and printer. Participants were also given pens, pencils, and highlighter pens. All participants first filled out the demographic questionnaire and were given 15 minutes to complete a writing sample, which was envisioned as a control variable. To ensure consistency of instruction, as well as to provide a measure to gauge the amount of time it took (efficiency) for the participant to research and write the report the entire session was recorded. The web cam was activated and participants were verbally instructed from a script that described the following scenario: Their employer was under a time constraint (heading to the doctor's office in an hour and 45 minutes), so they were to do their best with the time and information provided. Their assignment was to arrive at an informed recommendation that the employer would discuss with the doctor as a preferred treatment. They were told that there was no right or wrong answer and their opinion was important. Participants were also given a printed reminder sheet of their task. The reminder sheet was an outline of the script, with a brief description of the one-page report requirement and the need to arrive at a recommendation supported by their research. In each of the three conditions, participants were given one hour and 45 minutes to research and write the report. When necessary, participants were given a verbal "20 minutes left" warning, and another five-minute warning towards the end.

When the report was complete, the researcher interviewed the participant, utilizing the funnel interview script. Participants were then debriefed on the study and told that a more detailed report would be made available to them after the study was completed.

Data Analysis

The scores on the efficiency (time) and quality (rubric and global grade) measures were analyzed using a between-subjects ANCOVA with condition (paper, computer, and computer with Internet and printer) as a between-subjects factor. We entered the following control variables as covariates: Gender, GPA, language proficiency, mother's education, and father's education, as well as a grammar score from the writing sample. The grammar score was obtained using Grammarly, an online program. English as a second language (ESL) was significant in all analyses and was therefore consistently retained as a covariate. The ESL variable had three scale points: (1) English as first language, (2) learned English before age 10, (3) learned English after age 10. GPA and father's education were significant covariates in the two-way analysis of covariance and were therefore used in that particular analysis.

Results

Table 1 details the means and standard deviations by condition for the time measure and rubric quality measure. No significant differences were found between any of the three conditions for efficiency and output quality as measured by the rubric.

For the global quality measure, a one-way analysis of covariance comparing the three conditions, with ESL as a covariate, revealed a significant effect of condition [$F(2, 63) = 3.16$, $p = .049$]. Follow-up analyses of covariance comparing each pair of groups and retaining ESL as a covariate showed that the global essay scores (with a maximum of 10) were significantly higher in the computer condition ($M = 7.35$, $SD = 1.11$) than in the real-world condition ($M = 6.27$, $SD = 1.80$) [$F(1, 43) = 7.00$, $p = .011$]. The paper condition ($M = 7.19$, $SD = 1.91$) was not significantly different from either the computer or the real-world condition.

Table 1. Rubric scores and time to complete the report in computer, printer, and real-world conditions

	Rubric Score			Time		
Condition	**M**	**SD**	**n**	**M**	**SD**	**n**
Paper Only	5.5	.67	21	1 hr 13 min	23 min	21
Computer Only	5.5	.36	24	1 hr 11 min	17 min	24
Computer, Internet, Printer, ("Real World")	5.4	.53	22	1 hr 8 min	22 min	22

Note: Differences between conditions were not statistically significant.

In order to unpack the finding that the global measure was significantly lower in the real world condition than the computer condition, we separated the participants in the real-world condition into two groups: those who chose to print and those who did not print. We then did a new one-way analysis of covariance dividing the participants into three groups, computer condition, real-world – printed, and real-world – did not print. The analysis of covariance (ANCOVA) was again statistically significant after controlling for ESL [F (2, 42) = 3.42, p = .042]. The group who printed had global quality scores that were intermediate between the computer condition and the real-world condition: Their reports were of better quality than those who did not choose to print in the real-world condition, but worse than those in the computer condition (see Figure 6). However, examining each pair of groups separately in a new analysis of covariance, after controlling for ESL, only the difference between the two extreme groups was significant (computer and real-world – did not print) [F (1, 37) = 5.45, p = .025]. We further examined the real-world condition to determine whether choosing to use the Internet made a difference in quality. Doing research on the Internet did not make a difference in the global quality score. No one surfed the Internet to visit task-irrelevant websites.

Given that we did not find a difference in writing quality according to whether information sources were read on the computer or on paper, we decided to look at participants' note taking, which is a more active way of using paper. For this analysis, we utilized the two significantly different conditions, computer and real-world as one of two independent variables in a two-way analysis of covariance, using ESL, GPA, and father's education as the covariates. The second independent variable was whether or not the participants chose to take notes using paper and pencil. After controlling for the covariates, this analysis revealed a significant interaction between note-taking and condition [$F(1, 39) = 5.38, p = .026$]. Note-taking greatly reduced the advantage of the computer condition over the real-world condition (see Figure 7).

Our descriptive analysis of the exit interviews revealed that, when asked what they preferred for studying, paper versus computer, participants overwhelmingly (60 out of 66) said they preferred paper. In addition, when asked what they preferred when asked to perform a task similar to the one in this study (i.e. writing a paper), 39 stated that they preferred information on paper, 8 preferred the computer, and 19 had no preference.

Discussion

Despite the fact that most participants stated they preferred paper to computer, no report quality or efficiency differences were found between those whose source materials were paper or computer. However, once "real world" conditions were introduced (Internet plus printer), report quality was significantly reduced relative to viewing

Figure 6. Global report grades for computer condition (n=24), real-world condition with printing (n=6), and real-world condition with no printing (n=16)

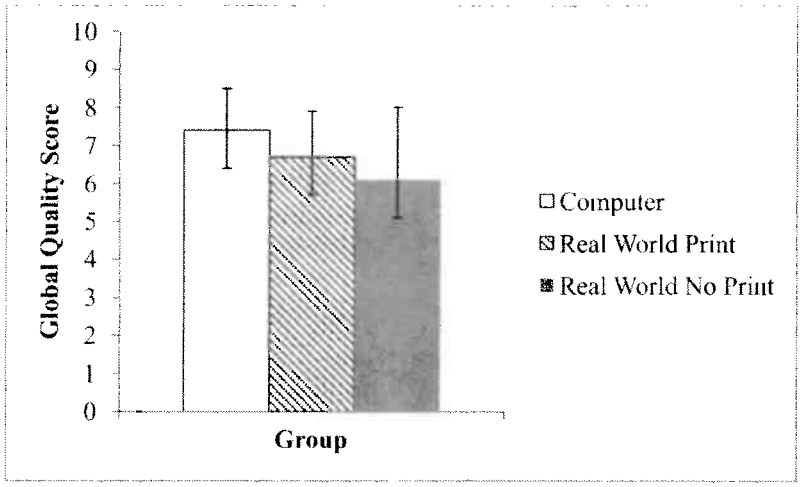
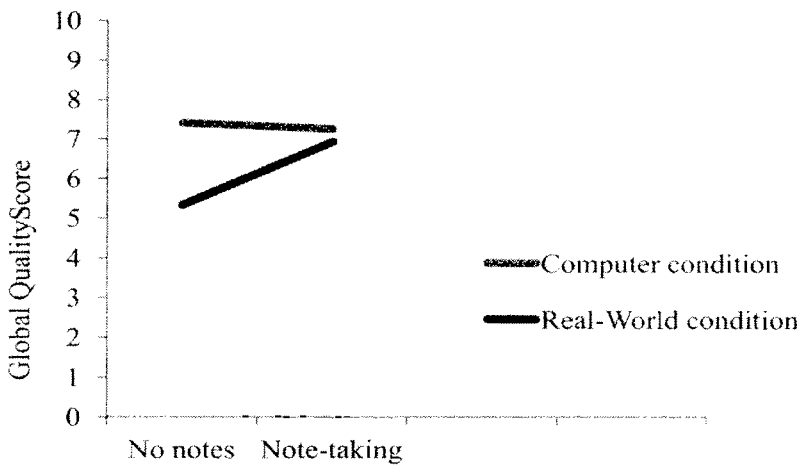


Figure 7. Global report grades as a function of condition and note-taking



source material on the computer without access to the Internet or a printer. Although the more passive use of paper to view source material did not make a difference in report quality, the more active use of paper through note-taking produced a significant interaction with condition, such that report quality in the real-world condition approached the higher quality of the computer condition.

It is also important to note that the differences manifested in the global scores rather than in the rubric scores. As mentioned before, the global score was an implicit measure of quality, meant to reflect real-world communication. Although it was informed by the more structured rubric, which served the purpose of a check-list to identify the components of the critical thinking aspect of this task, the global

score may more clearly reflect true critical thinking and communication.

GENERAL DISCUSSION

Electronic screens such as those found on computers, laptops, tablets, and e-book readers have become pervasive (Brenner, 2013; Zickuhr, 2013). Over the last several years, they have come to be used more and more to read text; and survey data suggest that we may be seeing a larger trend from paper to screens for reading and processing text (Pew Research Center, 2012; Rainie, Lee, & Duggan, 2012). Data from the participants in the two studies partially corroborate these trends. Consistent with survey data, all of the students in Study 1 had access to a computer and about a third had access to a specialized e-book reader or a tablet computer; there also appeared to be a shift toward reading on electronic sources.

However, despite the fact that reading source material on paper did not improve report quality, participants in Study 2 reported that they preferred to read and evaluate source materials on paper. Such a preference for paper is consistent with the findings of a study of older and younger German adults (Kretzschmar et al., 2013). Possible reasons for this preference may be a cultural bias (Kretzschmar et al., 2013) and habit. However, this may become a thing of the past as cost, environmental, and logistical concerns favor electronic access; digital books are cheaper (Howard, 2013), save trees, occupy less physical space, and are more portable. Even though today's college students are in some ways digital natives (Prensky, 2001), for many, their first exposure to books was probably on paper. As infants and toddlers' initial exposure to books occurs on iPads and other touch-screen devices, it is possible that we may see a shift toward preferring electronic sources.

While the more passive use of paper to read did not make a difference in either Study 1 or 2, the more active use of paper in note-taking did improve report quality in the real-world condition in Study 2, bringing it to the level of the computer condition. Recall that note-taking did not make a difference in reading comprehension in Study 1. Therefore, the positive effect in Study 2 suggests that the active creation of paper-and-pencil notes reduced the distracting effect of adding Internet access and printing capability in the more complex report-writing task.

Consistent with prior research on college students' multitasking (Junco & Cotten, 2012; Levine et al., 2007), our participants (Study 1) reported that they were moderate multitaskers and also reported multitasking when reading on screens and paper for both school and pleasure. Since reading on screens is tied to such multitasking and potential distractions, any investigation of the effect of different reading media must factor in this reality if the results are to apply to everyday reading and learning situations.

We had undertaken these studies to investigate whether electronic screens might impact how learners read and process text. Because the effect of the reading medium may be different for different tasks, Study 1 used a standard reading task and Study 2 used a more complex report writing task involving reading and synthesizing information from multiple source materials; additionally, Study 1 used an easy and a difficult passage to test the possibility that the medium impacts reading comprehension when reading cognitively more challenging text. We also used a variety of measures to assess the effect of the medium – including multiple-choice reading comprehension questions and reading/study time in Study 1 and a detailed rubric and global quality rubric for Study 2. For none of these varied measures of reading and writing did medium make a difference.

Finally, since reading on screens often occurs while multitasking, we manipulated whether participants could multitask – using the Internet and their own cell phone in Study 1 and only the Internet in Study 2. The common thread in the two studies was that the conditions that provided the option for multitasking had a bigger effect on performance than medium per se. The effects were not totally consistent

however. The multitasking condition in Study 1 decreased efficiency (that is, significantly increased time spent reading/studying); however, there was no indication that the actual extent of their multitasking impacted their comprehension. In contrast, the real-world condition in Study 2, with the option of accessing the Internet and printing, decreased report quality, although somewhat less so for those who printed and barely at all for those who used paper and pencil to take notes. Yet actually utilizing the Internet did not make a difference in report quality. Across both studies, the overall finding concerning the medium was that getting information on a screen compared with paper did not make a difference either in reading comprehension or in the synthesis of information for a persuasive report that required critical thinking.

Role of the Medium and Multitasking

Drawing on the Vygotskian notion of cultural tools (John-Steiner & Mahn, 1996), the process of cognitive socialization (Greenfield, 1993), and prior research with television and computer games (Subrahmanyam & Greenfield, 2008), we had speculated that electronic screens might also impact the reading and processing of text. However, across two studies conducted at two laboratories with student participants at different public universities in Los Angeles, we found that the reading medium did not impact different aspects of reading and writing performance in experimental tasks of varying levels of cognitive difficulty.

Our lack of significant differences is consistent with the findings of some prior research that has compared paper with screens (Dillon, 1992; Holzinger et al., 2011; Margolin, Driscoll, Toland, & Kegler, 2013; Noyes & Garland, 2003). In contrast to these studies, we had specifically utilized different tasks and manipulated task difficulty in Study 1 to address the possibility that paper might lead to better performance for more difficult tasks requiring more in-depth reading strategies and processing (Jamali et al., 2009; Liu, 2005). Additionally when synthesizing information across different source materials as in Study 2, we speculated that it might be easier to find and locate information on different sheets of paper compared to switching between different windows/screens. This report-writing task was, moreover, the most complex task of all.

Our lack of significant differences between paper and screens for information processing could have several reasons. One factor could be the particular tasks that we used: the passages used in Study 1 might not have been long enough and the difficult passage might not have been cognitively demanding enough to require more in-depth reading. Additionally, reading and answering comprehension questions and writing a report using different source materials might have been familiar tasks for our college student participants. Thus, it is possible that paper and screens as a reading medium are equivalent for cognitively easy and familiar tasks. Another factor could be that the participants were not motivated and so were not engaged with the task. Our participants were college students and most participated in the study for course credit that they received regardless of how they performed on the tasks. Finally, both studies assessed performance immediately after reading the text/source materials and it is possible that processing differences are not evident immediately after but occur over time. Future research should use a variety of unfamiliar tasks as well as manipulate motivation and time of testing to test these alternative possibilities.

When comparing the effect of the reading medium, it is also important to examine age and developmental effects. Most of the prior research (Dillon, 1992; Holzinger et al., 2011; Noyes & Garland, 2003) and our own studies were on college students or adults, who presumably had considerable practice with the experimental tasks of reading and processing information. It is possible that the medium might not impact performance when a cognitive activity such as reading becomes automatized and familiar, but may do so for

novices or when an individual is first learning the activity. In fact, the study by Mangen and colleagues (2013) that found an advantage for paper was done with 10th graders. Follow-up studies should examine the effectiveness of the reading medium among beginning readers such as kindergarteners and young elementary school children to see whether the medium might make a difference when reading has not become an automatized activity.

In contrast to the reading medium, we found some effects for multitasking. One robust effect of multitasking was on efficiency – in Study 1, we consistently found that multitasking increased reading and studying time regardless of medium or passage type. While this is not an unexpected finding, this is one of the first experimental demonstrations showing that multitasking while reading increases the time that students may need to sufficiently learn the material. Additionally, much of the prior research on multitasking while reading has used experimental simulations (Fox et al., 2009; Tran et al., 2013); such experimenter-directed multitasking simulations have typically held the reading time constant and thus have limited ecological validity. By not controlling the time and allowing participants to multitask and read as they normally would, we were able to show that multitasking decreased efficiency, with greater effects when one switched more often between reading and going online or using the cell phone.

It is also important to note that the effect of multitasking might be moderated by the medium, as we found a trend toward reduced reading time when reading on paper during multitasking conditions compared to the laptop and tablet. Participants' self-report about their habitual multitasking as well as their multitasking in the experimental task indicate that multitasking while reading might be more efficient when done on a different device than the reading medium. Future research should address this possibility using eye-tracking data to record eye movements when switching between different windows on different devices versus the same device.

We found less robust and more contradictory effects of multitasking on report writing and comprehension. In Study 2, we found lesser global report quality among participants in the real-world condition, where participants had access both to the Internet and to a printer. By contrast in Study 1, we found no consistent disruptive effect of multitasking on reading comprehension; more switches to cell phones and the Internet caused longer reading times, but had no effect on comprehension. However, collapsing the data from laptop and screen conditions, we found improved reading comprehension when participants read the easy passage on paper and multitasked. As noted earlier, one reason for this might be that the multitasking occurred on a device separate from the reading medium and so did not disrupt reading comprehension. Another possibility is that multitasking increases focus when engaged in easy tasks and decreases performance only under certain circumstances such as under time pressure or for difficult and challenging tasks; as noted earlier, the difficult passage in Study 1 might simply not have been challenging enough for our participants.

It is also worth noting that in Study 1 where there were no time constraints (participants were told to take as long as they wanted), there was no consistent disruptive effect of multitasking on comprehension; in contrast, Study 2 did have a time limit, and here access to the Internet and a printer did reduce quality on the global rubric. Future research should use more challenging math and problem solving tasks and manipulate time pressure to better understand how multitasking might impact task effectiveness.

Implications for Formal and Informal Learning

Given the increased use of e-books both in and out of the classroom (Blume, 2013; Hu, 2011; Rockinson-Szapkiw, 2011), it is important to examine whether paper and screens as a reading medium are equivalent with regard to efficiency and effectiveness when reading and studying. Although preliminary, our studies' findings

indicate that the medium might not matter when students are engaged in simple, familiar, or low-stakes tasks involving reading, processing, and synthesizing information, especially under no time pressure.

We need to reconcile the fact that Study 1 did not find that highlighting or note-taking made a difference for reading comprehension, whereas Study 2 found that note-taking had a positive effect on report quality in the real-world condition. This discrepancy may be attributed to the fact that the report-writing task used in Study 2 not only involved reading comprehension, but also selecting sources, synthesizing sources, and utilizing them to write a coherent report. Hence, its cognitive requirements went way beyond the task demands of reading comprehension. A complex task combined with the potentially distracting environment of the real-world condition may be what gave note-taking its positive effect.

For learners, this may mean that they have to be more strategic about which medium or media forms they use when engaging in unfamiliar and cognitively complex tasks. In fact, as screen based devices proliferate, it may not be a question of whether to use paper or a screen; more important may be knowing when and how to use them separately or together.

The role of multitasking in formal and informal learning is equally complex. Switching between tasks in the workplace is claimed to increase worker efficiency (Brown, 2010) and multitaskers often overestimate the advantages they derive from informal multitasking (Ophir et al., 2009). At the same time, experimental research using dual task paradigms have found reduced attention and lower performance when doing tasks simultaneously (Pashler, 1994; Rubinstein, Meyer, & Evans, 2001). Although we found no consistent disruptive effect of multitasking on effectiveness, our results suggest that switching between reading text and going online or using the cell phone results in longer study time and raises the possibility that such switching may disrupt performance under time pressure.

For learners, this means they have to be strategic about when and how they multitask –forgoing multitasking when time is short and/or the task is very complex or multitasking with a separate device when reading on paper. Given how ubiquitous multitasking has become, it is important make students of all ages aware of their own multitasking behaviors. Metacognition or thinking about thinking is a key factor in student success at all levels (Laskey & Hetzel, 2010), and we suggest that students may similarly need to develop meta-multitasking abilities to better regulate their reading and multitasking behaviors.

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REFERENCES

Ackerman, R., & Goldsmith, M. (2011). Metacognitive regulation of text learning: On screen versus on paper. *Journal of Experimental Psychology. Applied, 17*, 18–32. doi:10.1037/a0022086 PMID:21443378

Ananiadou, K., & Claro, M. (2009). *21st century skills and competences for new millenium learners in OECD countries (No. 41)*. OECD Publishing. doi:10.1787/19939019

Blume, H. (2013, June 18). L.A. school board OKs $30 million for Apple iPads. *Los Angeles Times*. Los Angeles. Retrieved from http://articles.latimes.com/2013/jun/18/local/la-me-ln-lausd-chooses-ipads-for-pilot-20130618

Bowman, L. L., Levine, L. E., Waite, B. M., & Gendron, M. (2010). Can students really multitask? An experimental study of instant messaging while reading. *Computers & Education, 54*, 927–931. doi:10.1016/j.compedu.2009.09.024

Braten, I., & Strømsø, H. I. (2006). Effects of personal epistemology on the understanding of multiple texts. *Reading Psychology, 27*, 457–484. doi:10.1080/02702710600848031

Brenner, J. (2013, June 6). Pew internet: Mobile. *Pew Internet and American Life Project*. http://pewinternet.org/Commentary/2012/February/Pew-Internet-Mobile.aspx

Brown, R. (2010). Multitasking gets you there later. *InfoQ*. Retrieved from http://www.infoq.com/articles/multitasking-problems

Daneman, M., & Carpenter, P. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19*, 450–466. doi:10.1016/S0022-5371(80)90312-6

Darroch, I., Goodman, J., Brewster, S. A., & Gray, P. D. G. (2005). The effect of age and font size on reading text on handheld computers. *HumanComputer Interaction, 3585*, 253–266. Retrieved fromhttp://dx.doi.org/10.1007/11555261_23

Dillon, A. (1992). Reading from paper versus screens: A critical review of the empirical literature. *Ergonomics, 35*, 1297–1326. doi:10.1080/00140139208967394

Dillon, A., McKnight, C., & Richardson, J. (1988). Reading from paper versus reading from screen. *The Computer Journal, 31*, 457–464. doi:10.1093/comjnl/31.5.457

Foundation for critical thinking. (n.d.). *Critical thinking testing and assessment: Rubrics for assessing student reasoning abilities*. Retrieved August 13, 2013, from http://www.criticalthinking.org/files/Critical Thinking Grid.doc

Fox, A. B., Rosen, J., & Crawford, M. (2009). Distractions, distractions: Does instant messaging affect college students' performance on a concurrent reading comprehension task? *Cyberpsychology & Behavior, 12*, 51–53. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19006461 doi:10.1089/cpb.2008.0107 PMID:19006461

Grabinger, R. S. (1993). Computer screen designs: Viewer judgments. *Educational Technology Research and Development, 41*, 35–73. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ465784&site=ehost-live doi:10.1007/BF02297311

Greenfield, P. M. (1993). Representational competence in shared symbol systems: Electronic media from radio to video games. In R. R. Cocking, & K. A. Renninger (Eds.), *The development and meaning of psychological distance* (pp. 161–183). Hillsdale, NJ: Lawrence Erlbaum.

Greenfield, P. M. (1994). Video games as cultural artifacts. *Journal of Applied Developmental Psychology, 15*, 3–12. doi:10.1016/0193-3973(94)90003-5

Greenfield, P. M. (2009). Technology and informal education: What is taught, what is learned. *Science, 323*, 69–71. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19119220 doi:10.1126/science.1167190 PMID:19119220

Greenfield, P. M., & Beagles-Roos, J. (1988). Radio vs. television: Their cognitive impact on children of different socioeconomic and ethnic groups. *The Journal of Communication, 38*, 71–92. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1460-2466.1988.tb02048.x/abstract doi:10.1111/j.1460-2466.1988.tb02048.x

Greenfield, P. M., Farrar, D., & Beagles-Roos, J. (1986). Is the medium the message? An experimental comparison of the effects of radio and television on imagination. *Journal of Applied Developmental Psychology, 7*, 201–218. doi:10.1016/0193-3973(86)90029-8

Hembrooke, H., & Gay, G. (2003). The laptop and the lecture: The effects of multitasking in learning environments. *Journal of Computing in Higher Education, 15*, 46–64. doi:10.1007/BF02940852

Holzinger, A., Baernthaler, M., Pammer, W., Katz, H., Bjelic-Radisic, V., & Ziefle, M. (2011). Investigating paper vs. screen in real-life hospital workflows: Performance contradicts perceived superiority of paper in the user experience. *International Journal of Human-Computer Studies, 69*, 563–570. doi:10.1016/j.ijhcs.2011.05.002

Howard, J. (2013, January 27). For many students, print is still king. *The Chronicle of Higher Education*. Retrieved from http://chronicle.com/article/For-Many-Students-Print-Is/136829/

Hu, W. (2011). Math that moves: Schools embrace the iPad. *The New York Times New York, 5*, A16. Retrieved from http://www.pearsonschool.com/drm/2010/ipadpilot/NY_Times_iPad_story_1-4-11.pdf

Jamali, H. R., Nicholas, D., & Rowlands, I. (2009). Scholarly e-books: The views of 16,000 academics: Results from the JISC National E-Book Observatory. *Aslib Proceedings, 61*, 33–47. doi:10.1108/00012530910932276

John-Steiner, V., & Mahn, H. (1996). Sociocultural approaches to learning and development: A Vygotskian framework. *Educational Psychologist, 31*, 191–206. doi:10.1080/00461520.1996.9653266

Junco, R., & Cotten, S. R. (2012). No A 4 U: The relationship between multitasking and academic performance. *Computers & Education, 59*, 505–514. doi:10.1016/j.compedu.2011.12.023

Kak, A. V. (1981). Relationships between readability of printed and CRT-displayed text. *Human Factors and Ergonomics Society Annual Meeting, 25*, 137–140. doi:10.1177/107118138102500136

Kingery, D., & Furuta, R. (1997). Skimming electronic newspaper headlines: A study of typeface, point size, screen resolution, and monitor size. *Information Processing & Management, 33*, 685–696. doi:10.1016/S0306-4573(97)00025-3

Kirschner, P. A., & Karpinski, A. C. (2010). Facebook and academic performance. *Computers in Human Behavior, 26*, 1237–1245. doi:10.1016/j.chb.2010.03.024

Kretzschmar, F., Pleimling, D., Hosemann, J., Füssel, S., Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2013). Subjective impressions do not mirror online reading effort: Concurrent EEG-eyetracking evidence from the reading of books and digital media. *PLoS ONE, 8*, e56178. doi:10.1371/journal.pone.0056178 PMID:23405265

Laskey, M. L., & Hetzel, C. J. (2010). Self-regulated learning, metacognition, and soft skills: The 21st century learner. *Strategies* (p. 17). Online Submission. Retrieved from http://files.eric.ed.gov/fulltext/ED511589.pdf

Levine, L. E., Waite, B. M., & Bowman, L. L. (2007). Electronic media use, reading, and academic distractibility in college youth. *Cyberpsychology & Behavior, 10*, 560–566. Retrieved from http://online.liebertpub.com/doi/abs/10.1089/cpb.2007.9990 doi:10.1089/cpb.2007.9990 PMID:17711365

Levine, L. E., Waite, B. M., & Bowman, L. L. (2012). Mobile media use, multitasking and distractibility. *International Journal of Cyber Behavior, Psychology and Learning, 2*, 15–29. doi:10.4018/ijcbpl.2012070102

Liu, Z. (2005). Reading behavior in the digital environment: Changes in reading behavior over the past ten years. *The Journal of Documentation, 61*, 700–712. doi:10.1108/00220410510632040

Liu, Z., & Stork, D. G. (2000). Is paperless really more? Rethinking the role of paper in the digital age. *Communications of the ACM, 43*, 94–97. doi:10.1145/353360.353370

Madden, M., & Lenhart, A. (2013). *Teens and technology 2013*. Retrieved from http://www.pewinternet.org/Reports/2013/Teens-and-Tech.aspx

Mangen, A., Walgermo, B. R., & Brønnick, K. (2013). Reading linear texts on paper versus computer screen: Effects on reading comprehension. *International Journal of Educational Research, 58*. doi:10.1016/j.ijer.2012.12.002

Margolin, S. J., Driscoll, C., Toland, M. J., & Kegler, J. L. (2013). E-readers, computer screens, or paper: Does reading comprehension change across media platforms? *Applied Cognitive Psychology, 27*, 512–519. doi:10.1002/acp.2930

Mayes, D. K., Sims, V. K., & Koonce, J. M. (2001). Comprehension and workload differences for VDT and. *International Journal of Industrial Ergonomics, 28*, 367–378. doi:10.1016/S0169-8141(01)00043-9

Muter, P., Latrémouille, S. A., Treurniet, W. C., & Beam, P. (1982). Extended reading of continuous text on television screens. *Human Factors, 24*, 501–508.

Noyes, J. M., & Garland, K. J. (2003). VDT versus paper-based text: Reply to Mayes, Sims and Koonce. *International Journal of Industrial Ergonomics, 31*, 411–423. doi:10.1016/S0169-8141(03)00027-1

Noyes, J. M., & Garland, K. J. (2008). Computer- vs. paper-based tasks: Are they equivalent? *Ergonomics, 51*, 1352–1375. doi:10.1080/00140130802170387 PMID:18802819

Oborne, D. J., & Holton, D. (1988). Reading from screen versus paper: There is no difference. *International Journal of Man-Machine Studies, 28*, 1–9. doi:10.1016/S0020-7373(88)80049-X

Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences of the United States of America, 106*, 15583–15587. doi:10.1073/pnas.0903620106 PMID:19706386

Paas, F., Renkl, A., & Sweller, J. (2004). Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. *Instructional Science, 32*, 1–8. doi:10.1023/B:TRUC.0000021806.17516.d0

Pashler, H. (1994). Dual-task interference in simple tasks: data and theory. *Psychological Bulletin, 116*, 220–244. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7972591 doi:10.1037/0033-2909.116.2.220 PMID:7972591

Paul, R., Willsen, J., & Binker, A. J. A. (1993). *Critical thinking*. Santa Rosa, CA: Foundation for Critical Thinking.

Pew Research Center. (2012). *In changing news landscape, even television is vulnerable*. Retrieved from http://www.people-press.org/2012/09/27/in-changing-news-landscape-even-television-is-vulnerable/

Prensky, M. (2001). Digital natives, digital immigrants Part 1. *Horizon, 9*, 1–6. doi: doi:10.1108/10748120110424816

Rainie, L., & Duggan, M. (2012). *E-book reading jumps: Print book reading declines*. Retrieved from http://libraries.pewinternet.org/files/legacy-pdf/PIP_Reading and ebooks_12.27.pdf

Rainie, L., Zickuhr, K., Purcell, K., Madden, M., & Brenner, J. (2012). *The rise of e-reading*. Retrieved from http://libraries.pewinternet.org/2012/04/04/the-rise-of-e-reading/

Rockinson-Szapkiw, A. (2011). Motivating students to learn: Is there a difference between traditional books and e-books? In S. Barton, J. Hedberg, & K. Suzuki (Eds.), *Proceedings of Global Learn Asia Pacific 235-239* (pp. 235–239). AACE International. Retrieved from http://digitalcommons.liberty.edu/educ_fac_pubs/185/

Rubinstein, J. S., Meyer, D. E., & Evans, J. E. (2001). Executive control of cognitive processes in task switching. *Journal of Experimental Psychology. Human Perception and Performance, 27*, 763–797. doi:10.1037/0096-1523.27.4.763 PMID:11518143

Schnotz, W., & Kürschner, C. (2007). A reconsideration of cognitive load theory. *Educational Psychology Review, 19*, 469–508. doi:10.1007/s10648-007-9053-4

Smith, A., Rainie, L., Lenhart, A., Purcell, K., Smith, A., & Zickuhr, K. (2011). *College students and technology*. Washington, DC. Retrieved from http://www.pewinternet.org/Reports/2011/College-students-and-technology/Report/Findings.aspx

Subrahmanyam, K., & Greenfield, P. M. (2008). Media symbol systems and cognitive processes. In S. L. Calvert & B.J. Wilson (Eds.), *Handbook of Children, Media, and Development* (pp. 166–187).

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*, 295–312. doi:10.1016/0959-4752(94)90003-5

Tran, P., Carrillo, R., & Subrahmanyam, K. (2013). Effects of online multitasking on reading comprehension of expository text. *Cyberpsychology: Journal of Psychosocial Research on Cyberspace*, 7, Article 2, doi: 10.5817/CP2013-3-2

van den Noort, M., Bosch, P., Haverkort, M., & Hugdahl, K. (2008). A standard computerized version of the reading span test in different languages. *European Journal of Psychological Assessment, 24*, 35–42. doi:10.1027/1015-5759.24.1.35

van der Velde, W., & Ernst, O. (2009). The future of eBooks? Will print disappear? An end-user perspective. *Library Hi Tech, 27*, 570–583. doi:10.1108/07378830911007673

Vygotsky, L. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Wexelbaum, R. S., & Parault, S. J. (2011). Ebooks and reading comprehension: Perspectives of librarians and educators. *Library Faculty Publications, Paper 2*. Retrieved from http://repository.stcloudstate.edu/lrs_facpubs/2

Zickuhr, K. (2013). *Tablet ownership 2013*. Retrieved from http://pewinternet.org/~/media//Files/Reports/2013/PIP_Tablet ownership 2013.pdf