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The effect of format on performance: Editing text in print versus digital formats

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Abstract
In light of the present-day proliferation of digital texts and the increase in situations that require active digital text reading in learning, it is becoming increasingly important to shed light on the comparison between print and digital reading under active reading conditions. In this study, the active reading abilities of 93 university students (83% females) were examined. Participants were asked to read, edit, recognize errors and improve the quality of short papers (600 words each) on the topic of environmental awareness, in both print and in digital formats. Surprisingly, and in contrast to many recent reports about print versus digital reading, no significant differences were found between the performances of participants in the two formats. Similarly, no significant differences were found for all categories of text errors as well as for gender. It was found that the digital readers completed their tasks faster than the print readers but their performance was not lower. Results of this study have important implications for the current debate in higher education concerning the use of digital text for learning and for designing, reviewing and editing academic works.

Introduction

In recent years, information consumers has faced a rapid growth in the availability of digital in lieu of the printed text as evidenced from the proliferation of online newspapers, electronic books, electronic encyclopedias, online academic journals and blogs (Birkerts, 2004; Cargill, 2011; Hamblen, 2011; Heider, Laverick and Bennett, 2009; Hillesund, 2008; The Economist, 2011; Vaughan, 2002), as well as the expansion of e-book readers (MacManus, 2009). This shift towards digital text is also evident in academia, where today, most texts are read in a digital format (Cargill, 2011; Heider *et al*, 2009; Nelson, 2008; Thayer *et al*, 2011).

Reading from digital displays—especially from computer screens—often creates severe usability problems that the readers must cope with (Altonen, Mannonen, Nieminen and Nieminen, 2011; Bus and Neuman, 2009; O'Hara and Sellen, 1997; Quinn and Stark-Adam, 2007; Van Den Broek, Kendeou and White, 2009). Among these problems are the large reading distance from a computer screen (as opposed to the short reading distance from a printed book), the long lines of text on the modern wide computer screens and the problem of shifting the eye gaze from line to line while reading (Evans, Charland and Saint-Aubin, 2009) and the blurring of text on compu-

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Practitioner Notes

What is already known about this topic

- Reading from digital displays—especially from computer screens—often creates severe usability problems that the readers must cope with.
- Many recent studies reported that reading from print and reading from digital displays differ significantly in a wide range of aspects.
- However, most recent studies focus on digital reading under passive conditions, in which text comprehension is tested without asking the reader to "act" on the text by editing, recognizing or correcting errors and improving the text's quality.

What this paper adds

- This research investigated active reading in print versus digital displays.
- Surprisingly, and in contrast to the commonly reported findings from print versus digital reading studies, no significant differences were found between the performances of participants in the two formats.
- No significant differences were found for six categories of text error as well as for gender.
- The digital readers completed their tasks faster than the print readers, but their performance was not lower.

Implications for practice and/or policy

- The unexpected absence of significant differences between print and digital formats supports the notion that digital reading has become an everyday practice among users, who have gained digital reading proficiency in recent years.
- Results of this study have important implications for the current debate in higher education concerning the use of digital text for learning and for reviewing and editing academic works.

ter monitors. In addition, the text fragmentation and the resulting decrease in the text's coherence (Albrecht and O'Brien, 1993; Ozuru, Dempsey and McNamara, 2009), which are associated with the nonlinear nature of the hypertext, harm text comprehension (Chang and Ley, 2006; Rouet, 2000; Van den Broek *et al*, 2009) and present readers with a high cognitive load (Ackerman and Goldsmith, 2011; Rouet, 2000) and a feeling of disorientation (Armitage, Wilson and Sharp, 2004).

The previously cited usability problems related to digital reading have led to extensive research efforts in order to characterize the nature of digital reading and learning, in comparison with reading from print (eg, Brown, 2001; Eshet-Alkalai and Chajut, 2007; Eshet-Alkalai and Geri, 2007; Evans *et al*, 2009; Garland and Noyes, 2004; Gulbrandsen, Scroeder, Milerad and Nylenna, 2002; Hartley, 2002; Hiebert, Menon, Martin and Bach, 2009; Quinn and Stark-Adam, 2007; Reinking, 2005), and to establish standards for effective digital text design.

Many recent studies reported that reading from print and reading from digital displays differ significantly in a wide range of aspects. Findings from these studies serve as the basis for many of the discursive comments made later in the paper. The major differences between print and digital reading are outlined in the next section:

- *Methodological reading*: print readers tend to read the text methodologically, line by line, whereas, digital readers tend to "jump" from place to place in the text as they read (Evans *et al*, 2009; Hillesund, 2010; Liu, 2005; Quinn and Stark-Adam, 2007).

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- *Reading pace*: reading from a digital display is slower and less accurate than from print (Altonen *et al*, 2011; Evans *et al*, 2009; Garland and Noyes, 2004).
- *Discomfort and disorientation*: readers of digital texts usually report fatigue and discomfort (Altonen *et al*, 2011; Chang and Ley, 2006; Lam, Lam, Lam and McNaught, 2009; Rouet, 2000; Rouet, Rouet, Epstein and Fayard 2003) and that the lack of a "physical text" creates a feeling of disorientation and problems in navigating easily through the text (Armitage *et al*, 2004; Lazar, Bessiere, Ciaparu, Robinson and Shniderman, 2003; Niederhauser, Reynolds, Salmen and Skolmoski, 2000).
- *Cognitive load*: many studies report that the nonlinear nature of reading from hypertext, as well as the attention shift that is involved in using the hyperlinks embedded in the digital text, results in a higher perceived cognitive load compared with print reading (Ackerman and Goldsmith, 2011; Niederhauser *et al*, 2000; Rouet *et al*, 2003; Van den Broek *et al*, 2009; Winter, Cotton, Gavin and Yorke, 2009).
- *Text design*: studies on the effect of text design on comprehension (eg, Dillon, 2004; Eshet-Alkalai and Geri, 2010) reported that the conversion of text from a print to a digital display and vice versa affects the quality of learning and usually results in reducing comprehension (Ackerman and Goldsmith, 2011), especially when a text that was designed to be read in print is scanned and read "as is" from a digital display (Eshet-Alkalai and Geri, 2010).
- *Ownership and readers' preferences*: studies of digital reading preferences (eg, Hillesund, 2010) clearly indicate that most readers prefer to read long, academic text in print, whereas they are willing to read short, news-like reports in a digital format (Ackerman and Goldsmith, 2011; Spencer, 2006). Nila, Sathe, Grady and Nunzia (2002) found that university students preferred reading from electronic journals, whereas the faculty staff preferred printed journals. Interestingly, Chang and Ley (2006) reported that the students who preferred reading academic text from the monitor were the higher achieving students. Usually, readers indicate that they prefer the printed version of papers because of the sense of ownership provided by the printed text (Armitage *et al*, 2004; Griffith, Krampf and Palmer, 2001).

In recent years, with the penetration of digital reading and writing technologies into higher education, submission of academic work in a digital format has become common practice in most institutions (Heider *et al*, 2009; Nelson, 2008; Thayer *et al*, 2011; Whitworth and Friedman, 2009). Consequently, students are required to submit seminar work, assignments and even examinations in digital format, and instructors are required to read, annotate and grade them in front of a digital display (Bus and Neuman, 2009). Many distance-learning academic institutes have even developed special environments for online submission and assessment of academic work. In recent years, there is growing indication of frustration among academic staff concerning inconvenience, workload and the problems that are involved in this process of online text editing and text assessment (Birkerts, 2004; Chang and Ley, 2006; Hartley, 2002; Heider *et al*, 2009; Vaughan, 2002). At the same time, concerns are raised as to the quality of online assessment and grading of academic papers and books compared with the quality of similar tasks in print (Altonen *et al*, 2011). Surprisingly, to the best of our knowledge, the research literature completely lacks studies that focus on active text editing of digital versus print formats. All studies on digital text comprehension test readers for their passive comprehension of text.

This research investigated *active reading* (ie, the reader's ability to edit a given text and demonstrate comprehension by identifying and correcting text errors) in print versus digital displays. Based on the numerous reports in the research literature on print versus digital reading (eg, Ackerman and Goldsmith, 2011; Eshet-Alkalai and Geri, 2007, 2010; Evans *et al*, 2009;

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Table 1: Text errors taxonomical framework utilized in this study

Mistype:
Typing error (eg, one incorrect letter)
Extra space within a word
Deleted space between words
Metathesis (eg, "aks" *instead of* "*ask*"
Homophonic errors (eg, "there"/"their")
Morphological errors
Gender errors (in Hebrew, there is a distinction between masculine and feminine verb conjugations)
Singular—plural
Numbers
Verb conjugation
Person
Definite article (*hey hayedia* in Hebrew or "the" in English)
Semantic errors
Syntactic errors
Clarity
Prepositions
Redundancy
Synonyms
New paragraph
Unsuitable paragraph
Punctuation

Hillesund, 2010; Quinn and Stark-Adam, 2007), we hypothesized that significant differences between the two formats will be found for all the categories of text errors.

Methodology

Participants

Ninety-three undergraduate social sciences students (82.8% females, 18.2% males) participated in the study. The average age was 23.9 (standard deviation [*SD*] = 4.40), with an age range of 19–40. All participants were born in Israel, and Hebrew was their native language. They all had personal computers and used them intensively—61.3% used computers for at least 2 hours per day, and 38.8% used them for 1 hour or less per day; 93.5% reported that they were proficient in the *Word* application.

Research tools

- Text errors taxonomical framework (Table 1): based on a literature review, we created a six-category taxonomical framework of text errors: mistyping, homophonic, morphologic, semantic, syntactic and clarity errors. This taxonomy was validated by five experts in linguistics and text editing. Only categories for which there was a 100% agreement between the experts were included in the taxonomical framework.
- Papers for analysis: Two popular papers of the same length (600 words), topic (environmental awareness) and author that were published in Hebrew in the *Galleria* magazine of the *Haaretz* newspaper were selected for this study. Each paper was changed by the researchers, and errors from each category of the taxonomical framework (Table 1) were embedded in it. In total, 51 errors and changes were embedded in each paper, divided equally between the different categories of text errors (Table 1). A pilot study was conducted in order to validate and improve the text errors and changes in each paper. The pilot study was composed of a group of five experts and 21 bachelor's degree university students. Participants in the pilot study were asked to identify the text errors, make corrections that improve the text clarity and explain them. The

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participants were interviewed in order to validate the embedded text errors. The two papers for analysis were revised, based on the findings of the pilot study, in two phases: only text errors about whose validity the experts had 100% agreement were left in the papers; text errors and changes that were easily identified, or text errors and changes that were not identified at all by the students, were removed from the papers.

- Demographic questionnaire: the questionnaire collected demographic data, such as gender, age, experience with technologies and self-report on learning disabilities.
- Reflection: participants were asked to evaluate their performance to reflect on their experience in correcting the two texts and to report on the difficulties they faced during the task. They were also asked for their preferred format: print or digital.

Task

The participants were given 20 minutes to read, correct and make improvements in each of the two papers without knowing the overall context of the experiment. Every participant corrected one paper in print, using a pen, and the other paper in digital format, using "track changes" feature of *Word*. Each paper was corrected in a different session, at least 1 week apart, so that the participants could not infer from the first session to the second. The order of formats and the texts was counterbalanced. Questionnaires were filled in after task completion.

Data analysis

Each participant's performance for the two papers was analyzed according to the text errors taxonomical framework (Table 1). Correction of the text errors and all other editorial changes made by each participant were classified into positive (changes that improved the paper's quality), negative (changes that harmed the paper's quality) and neutral (unnecessary changes that did not affect the paper's quality). The participants' performance for each category was summarized in order to assess their performance.

In order to allow a comparison of the participants' performance in print and digital formats and a correlation between their performance in the different categories and subcategories of the text errors framework (Table 1), a new error correction index (ECI) was established and calculated for each participant as follows:

ECI = total positive text corrections, minus total negative text corrections, minus total unidentified errors, divided by sum of errors.

Since a normal distribution of ECI values was found in all categories of the text errors framework (except for the syntactic category), we used a categorical distribution in analyzing the data from both print and digital formats.

Findings

No significant difference was found between the average score of participants in the two formats: print = 30.40% ($SD = 0.14$) and digital = 30.10% ($SD = 0.15$), $t = .30$, $df = 88$, NS). The relatively low score in both formats clearly indicates that the tasks were not easy for the participants.

The correlation between the categories and subcategories of the text errors framework (Table 1) was checked with Spearman correlation. Medium–strong correlations were found between all the categories, in other words: participants' performance in each category was similar for both print and digital formats and participants who performed highly in one format also performed highly in the other (Table 2).

In order to examine the correlation and performance differences between the ECI values for the text errors categories and subcategories in print and in digital formats, a Pearson's test and a *t*-test were conducted (Table 3).

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Table 2: Correlation (r) between performance in all categories—print format versus digital format (n = 90)

	Mistype	*Homophonic*	*Morphological*	*Semantic*	*Syntactic*	*Clarity*
Mistype						
Print format	—	.39**	.49**	.53**	.16	.45**
Digital format	—	.49**	.62**	.50**	.25*	.46**
Homophonic						
Print format		—	.55**	.56**	.31**	.50**
Digital format		—	.58**	.44**	.34**	.48**
Morphological						
Print format			—	.65**	.17	.57**
Digital format			—	.60**	.24*	.71**
Semantic						
Print format				—	.14	.63**
Digital format				—	.04	.50**
Syntactic						
Print format					—	.43**
Digital format					—	.32**
Clarity						
Print format						—
Digital format						—

*$p < .05$; **$p < .01$.

Table 3: Editing text in print versus digital formats: correlation and performance differences between error correction index values

	Print Format		*Digital Format*			
Variable	*Mean*	*SD*	*Mean*	*SD*	*R*	*T (df = 88)*
Mistype	.44	.37	.44	.41	.30**	–.04
Homophonic	–.05	.59	.09	.62	.46***	–2.08*
Morphological	–.33	.42	–.34	.41	.63***	.18
Semantic	–.39	.52	–.41	.43	.58***	.48
Clarity	–.51	.35	–.52	.37	.74***	.63

*$p < .05$; **$p < .01$; ***$p < .001$.
Because of the bimodal distribution found for the syntax category, it is missing from the table. A chi-square test was conducted instead (see explanation in the "findings" section).

As shown in Table 3, the significant positive correlation between the performance of participants in print and in digital formats indicates that participants who performed well in one format also performed well in the other. No significant differences were found between the print and digital formats, except for the homophonic category. Future studies might explain this result.

A Cohen's *d* was used in order to check the effect size. A small significant difference was found between the two formats except for a minor difference in the homophonic category (Cohen's $d = 0.23$).

In contrast to the normal distribution of values found for all other categories, a bimodal distribution was found for the syntax category. Therefore, the more suitable chi-square test was performed for this category. Results of this test show a connection between the performance in digital format and the performance in print format ($\chi^2 = 10.53$, $df = 4$, $p < 0.05$), or in other words, the participants' performance in one format was similar to their performance in the other.

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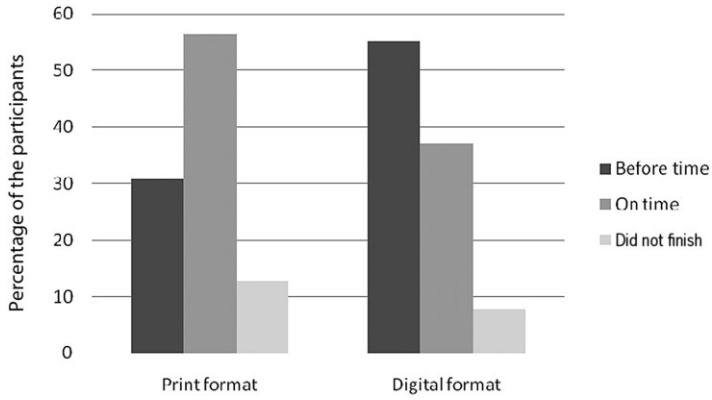

Figure 1: Task completion in print versus digital formats

In order to examine whether the order of presenting the two reading conditions (print and digital) affected the participants' performance, and if there was a transfer to the second condition after doing the first one, a mix model test was done. No interaction was found between the order of presenting the tasks and the performance of the participants. This implies that the counterbalance method employed in this study was accurate.

In order to examine demographic variables, tests both within and between subjects were conducted. No significant differences were found in computer usage intensity as well as in mastery level of using *Word*.

Interesting differences between the print and the digital formats were found for the time duration required for participants to complete their tasks (Figure 1). Despite the fact that time required to complete the task had no effect on the participants' performance, as shown in Figure 1, in the digital format, most of the participants completed their task before time, whereas in the print format, most of the participants completed their task on time ($\chi^2 = 32.41$, $df = 4$, $p < 0.001$).

No clear difference was found in format preference: 50.3% of the participants favored the print format and 45.3% favored the digital format, while 4.7% had no preference. No interaction was found between format preference and the participant's performance.

Discussion and conclusions

Recent research literature on reading (eg, Castillo, 2010; Hillesund, 2010; Liu, 2005; Quinn and Stark-Adam, 2007) clearly suggests that print and digital formats should be regarded as two distinct entities that differ from each other in a wide range of aspects such as reading pace, comprehension, discomfort and disorientation of reading, cognitive load and readers' preferences.

Studies of text comprehension in print versus digital formats report on distinct differences between these two types of display. Rouet *et al* (2003) and Van Den Broek *et al* (2009) found a lower comprehension in the digital display—findings that they relate to the higher cognitive load involved in digital reading. On the other hand, Ackerman and Goldsmith (2011) suggested that the differences in text comprehension between print and digital formats result from differences in metacognitive regulatory processes, which are dictated by the two formats. They found no differences in text comprehension when reading time was limited. However, when there was no limit on the time allotted for reading the text, they discovered that reading time was shorter for the digital readers and that the comprehension for the digital text was lower than for the print. In our study, time allotted for reading was limited, and therefore, our finding of no difference between

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print and digital reading is similar to the findings of Ackerman and Goldsmith (2011), Gulbrandsen *et al* (2002) and Hartley (2002) that no differences in performance occur under time-limited conditions. Similar to Ackerman and Goldsmith (2011), in our study, digital readers completed their task earlier than the print readers. Eshet-Alkalai and Geri (2007, 2010) compared text comprehension in print and digital formats as expressed by the ability to exercise critical reading tasks. They found that younger readers read text more critically in a digital format, whereas older readers read the same text more critically in a print format.

Despite the previously cited wide range of research reports on differences between print and digital reading, findings of the present study clearly suggest that there is almost no performance difference between these two formats. The fact that in our study, this finding was found consistent for all the categories of text error (Table 1) and subgroups (eg, gender) reinforces the validity of the research methodology and of the findings. In addition, the fact that for each format, the participants were able to identify only about 30% of the errors clearly indicates that our finding, of no difference between print and digital reading, is not a ceiling effect that results from too easy tasks.

Our findings can be explained in terms of three different points of view. According to the *active versus passive methodology* explanation, to date, most studies on print versus digital reading were conducted under passive conditions, in which participants were tested for text comprehension without the need to act on the text by editing it. The present study was conducted under "active reading" conditions in which participants were tested for their ability to demonstrate comprehension by revising and editing a given text. We therefore suggest that our findings, which are contradictory to the common findings in recent print versus digital studies, may result from the difference in research methodologies (passive vs. active) that were utilized. More research on active reading is needed to shed light on this issue.

According to the *gaining proficiency* explanation, in recent years, there has been a growing body of research evidence (eg, Altonen *et al*, 2011; Eshet-Alkalai and Chajut, 2009, 2010; Lam *et al*, 2009) that illustrates the pivotal role of experience in the performance of digital users—in contrast with the digital natives' approach of Prensky (2001), which relates performance differences to the age of users (in the current study, the average age was 23.9). Some recent studies even questioned the validity of the term "digital natives" (eg, Helsper and Eynon, 2010; Salajan, Schönwetter and Cleghorn, 2010). Eshet-Alkalai and Chajut (2009, 2010) showed that over a period of 5 years, the gap between users of different technological platforms closed as the users became proficient in using these platforms. It is possible that our findings reflect the fact that after many years of reading text online, present-day young readers have already gained equal mastery of digital reading and of print reading. This trend, of closing the gap between print and digital reading, is illustrated clearly by recent reports (eg, Fenn and LeHong, 2011) that suggest that today, digital information consumption almost equals the consumption of information in print, and by the fact that in 2010, sales of e-books in *Amazon* for the first time exceeded sales of printed books (The Economist, 2011).

According to the *information economics* explanation, the basic premises of information consumption are that information does not have an absolute universal value (Ahituv, 1980), that people differ in their preferences for information representation formats and that their performance is affected by these preferences (Speier, Vessey and Valacich, 2003). Saranto and Hovenga (2004) claimed that the familiarity of information consumers with the information format increases the real value they assign to the information. This idea is supported by the study of Morineau, Blanche, Tobin and Guéguen (2005), who claimed that the lower performance of digital readers compared with print readers resulted from the lower value they assign to the digital document. In terms of the information economics principles, our findings of no performance difference

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between the print and the digital formats may indicate that present-day readers perceive the digital and the print formats as having an equal value and, therefore, perform similarly in these two formats. The performance differences between older and younger readers in print versus digital reading, which was found in 2005 by Eshet-Alkalai and Geri (2007), may reflect the trend of closing, over time, the gap between the two formats, formats that are perceived as having a similar value by today's readers. This idea reinforces the gaining proficiency explanation discussed earlier.

Results of the present study should be considered in light of the following constraints: first, the study employed an innovative text errors taxonomical framework that should be elaborated and revalidated in future studies. Second, due to the preference of females for social sciences, the sample in the present study, which was composed of social studies university students, had more females (82.8%) than males (18.2%). Future studies on more balanced samples may clarify whether results of the present study are consistent in more gender-balanced groups. Third, the text that was used in this study was relatively short (1.5 pages). In future studies, it should be tested whether no difference in performance between print and digital text remains also in longer papers, which are common in academic reading. Fourth, the papers used in this study were focused on environmental issues. In future studies, papers from different topics should be used in order to test the effect of the paper's topic on the reading performance.

In conclusion, findings of this research shed light on the nature of present-day active reading from print and from digital displays. If these findings can be replicated, then the results can be used to improve the integration of digital texts, in general, and of electronic books, in particular, in academic teaching and learning (Thayer *et al*, 2011). More research on print versus digital reading under active conditions is necessary in order to clarify the nature of digital reading and of the long-range changes it undergoes.

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