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The impact of paper-based versus computerized presentation on text comprehension and memorization

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ABSTRACT

We compared the effects of two media (paper vs. computer) on reading comprehension and memorization among students in their third or fourth year of secondary school. To assess comprehension, we constructed and validated a text with a carefully controlled hierarchical structure, accompanied by a questionnaire containing three types of questions (surface, semantic, inference). Memory of the text was assessed with a test based on the Remember-Know (R/K) paradigm. The results of the comprehension and R/K tests indicated that there was no difference between the two media. Regardless of medium, surface comprehension was better than either semantic or inference comprehension. The R/K test indicated that memorization was better for the surface elements of the text (more R than K responses). In conclusion, overall results show that if we fulfil all the conditions of paper-based versus computerized presentation (text structure, presentation on a single page, screen size, several types of questions measuring comprehension and memory performances), reading performances are not significantly different.

1. Introduction

Some years ago, there was a debate about the benefits or otherwise of different media for learning. Clark (1983, 1994) asserted that the nature of the medium does not affect learning. For this author, what influences learning more is the authenticity of the task or problem. By contrast, Kozma (1991, 1994) suggested that the nature of the medium could have an impact on students' cognitive skills. Now that technology and the media have become an integral part of the education system, this debate has moved on. We can now accept that "both medium and method are important elements in the design" (Moffat, 2013). In the present study, we revisited the debate on the equivalence of computer-based and paper-based tasks. Results in the literature show consensus on the influence of medium on reading (for a review, see Noyes & Garland, 2008). However, while some studies indicate that reading is more difficult on a computer screen than on paper (Mangen, Walgermo, & Bronnick, 2013), others imply that there is no difference between the two (Krug, 2006; Noyes & Garland, 2008; Shneiderman & Plaisant, 2009). Noyes and Garland (2008) suggest that the results depend on the assessment criteria, and that some tasks are more appropriate than others for a given medium.

Several reasons have been put forward by authors to explain differences in performance (reading speed and/or comprehension) between computer and paper.

Some of the first studies to assess reading from paper versus computer clearly showed that participants performed better when reading from paper, usually in terms of reading speed. Lower reading speeds (20–30%) for computer-displayed texts compared with printed materials (Bailey, 1999; Dillon, 1992) have been attributed to the fact that people are more used to reading from paper (Dillon, 1992).

However, other early studies assessing reading from paper versus computer reported less clearcut results, often again in terms of reading speed. When Meyer and Poon (1997) investigated computerized presentations, they found that young adults had higher reading speeds and better text comprehension than older people. The authors attributed this result to generational differences and the fact that older people are less familiar with computers. Kurniawan and Zaphiris (2001) examined the effect of

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information layout (one, two or three columns) on reading from a computer or from paper in three groups of participants aged 18–65 years. Their results showed that reading was faster (10–30%) from paper than from a computer when the text was presented in one or two columns. By contrast, they failed to find any difference between the two media when the text was presented in three columns. There was also no difference in either medium in participants' preferences regarding the number of columns for text layout. When Mayes, Sims, and Koonce (2001) studied differences in reading speed between paper and computer, they found conflicting results. In the first of two experiments, they found that participants read faster from paper. However, in their second experiment, where they asked half the participants to memorize a list of letters while reading, they observed the opposite effect. They concluded that what is important is how the information is displayed. Similarly, Noyes and Garland (2003) studied students' reading comprehension on paper and on computer by calculating the numbers of right answers they provided and their reading times. The same text was used for both paper and computer, and participants were given 20 min to read it. Participants answered 20 multiple-choice questions. After the test comprehension task, reading speed was measured by giving participants a different page of text to read as quickly as possible. Results showed that there was no difference in either the numbers of correct answers or reading times between paper-based and computer-based presentations. The authors contended that control of the shaping material explains the equivalence between playback on computer and on paper.

More recently, studies assessing reading from paper versus computer have included other assessments besides reading speed, such as comprehension and recall. Some of these studies again found that performances were better for paper. In a study assessing the reading from paper versus computer of two descriptive texts (372 and 411 words) by children in the fifth year of primary school, Kerr and Symons (2006) measured reading time, comprehension and recall via questions about the content of the texts and questions requiring inferences. Results indicated that the students read more slowly from the computer, but recall more information. However, they were more effective in understanding the texts when reading from paper. In another study assessing recall, Johnson and Nádas (2009) showed that participants had poorer recall on screen, with more difficulty remembering the location of details in the texts. Wästlund, Reinikka, Norlander, and Archer (2005) conducted two experiments comparing students' reading from paper versus computer, to measure written production and comprehension. In the first experiment, participants read 10 pages of .pdf documents containing five different texts (mean length per text: 1000 words). The reading phase was followed by a multiple-choice questionnaire (the READ test measuring reading comprehension in Swedish). In the second experiment, participants read short newspaper articles (mean length per article: 70 words) and had the task of finding an appropriate title for each article. The time allocated to reading was limited in both experiments. The authors found that in both experiments, performance were poorer on the computer than on paper, in terms of both written production and comprehension. In addition, participants in the computer condition reported higher levels of stress and fatigue than those who read paper. Wästlund et al. (2005) concluded that reading and working on a computer generates a higher cognitive load. According to the authors, scrolling information on the screen requires readers to consciously focus on the text and how to move it, and this behaviour requires more cognitive resources than turning a page, which is a simple – and more automatic – gesture.

However when participants' comprehension is assessed with different types of tasks, and when the length of the texts, their content or the age of participants is took as an experimental variable, performances on screen can become just as good as those on paper (if not better) in certain conditions (Ball & Hourcade, 2011), although in other conditions, the superiority of reading from paper persists (Mangen et al., 2013). For example, in a recent study designed to replicate that of Meyer and Poon (1997), Ball and Hourcade (2011) administered a reading task (from Wikipedia) in their first experiment. They assessed comprehension and reading speed as a function of screen size (three different sizes) in three groups of participants (children, young adults, older adults), who had to answer a questionnaire consisting of six multiple-choice questions. The researchers also studied the effect of familiarity on graph comprehension (a familiar histogram line and an unfamiliar scatterplot). Results showed that the older participants performed better than the young adults and children, in terms of reading speed and comprehension of the text on the computer. They also showed that screen size had no effect on reading speed and comprehension. By contrast, the older participants performed more poorly than the other two groups on comprehension of the unfamiliar graph (scatterplot). These results therefore show that it is familiarity and the individual's prior experience that influence performance, as in the study by Meyer and Poon (1997). In their second experiment, with young and older adults, Ball and Hourcade (2011) studied the comprehension of texts taken from *Scientific American* (considered difficult) using a questionnaire and a gap task featuring a text with 10 missing words. The authors manipulated the length of the journal texts (long vs. short), and presented them on paper and on a computer in .pdf format. Results showed that performances were better for long texts than for short ones, and that older people performed better than young adults, but there were no significant differences between paper and computer. These results suggest a decrease in intergenerational differences. Mangen et al. (2013) studied the reading of narrative and descriptive texts from a computer (.pdf format, with a resolution of 1280 × 1024) and from paper (A4 format) among secondary-school students aged 15–16 years, as in the PISA assessments. The texts contained 1400–1600 words, as well as graphics and illustrations. After each text had been read, the text remained visible while students performed a comprehension test. Results showed that there was no difference between the two types of text when they were read from a computer, but performances were poorer than in the paper-based presentation condition. The authors attributed the poorer computer-based performances to having to scroll or click on the .pdf file, whereas in the paper condition, students kept the text in their hands and moved quickly from page to page. Keeping in touch with all the text in this way, from beginning to end, could be a way of decreasing cognitive load, according to the authors, and thus of having more resources to allocate to text comprehension.

In summary, the results and conclusions about these media are quite divergent. Reading comprehension seems to vary according to the reader's interest, the length of the text, its structure, and the purpose of the reading, be it learning or entertainment (Ball & Hourcade, 2011). We can also see that changing practices, the increasing use of computers, the growing number of older people using computers, and children's use of new digital tools from an early age have transformed the skills and abilities of study participants in terms of reading speed and reading comprehension (Meyer & Poon, 1997). There is also evidence that improvements in digital tools have reduced differences in performance between paper and computer. Various media-related parameters can influence participants' performances, such as screen size (Sabri, Ball, Bhatia, Fabian, & North, 2007) or text layout (Kurniawan & Zaphiris, 2001). Nevertheless, as we have seen in the studies described above, the question of the equivalence of computer- and paper-based tasks has yet to be resolved. In these studies, in order