

# Investigating Computer Screen and Paper Reading Speed Differences

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**Abstract:** This paper presents the results of an experiment measuring the difference of reading speed and preference when reading on paper or screen. Extending previous experiments on the topic of reading speed measurements, which usually concentrate in specific age groups, in this experiment, forty two participants from across the adult life span took part in reading on computer screen or on paper. Results are in agreement with previous studies, which showed that reading from paper is significantly faster (around 10-30%) than reading from screen. No significant differences in terms of reading speed and preference among the three information layouts (one-column, two-column and three-column formats) used in this experiment were found.

## Introduction

With the exponential increase of the use of the web for daily activities (searching for information, reading news) reading has shifted more and more from paper to screen.

Reading online occupies the majority of user time when visiting a website, triggering a large number of studies investigating factors affecting reading of electronic text. Muter and Maurutto (1991) listed a number of differences between reading from paper and screen that may account from the slower reading speeds on screen (Distance between the reading material and the reader, Angle of the reading material, Character shape, Resolution, Characters per line, Lines per page, Words per page, Inter-line spacing, Actual size of characters etc.)

Studies found that reading from papers is 20-30% faster than reading from monitors (Bailey, 1999) although Nielsen (1998) suggested that with better screen resolution (300 dpi) the reading speed from the monitor will equal the reading from paper.

Ziefle (1998) investigated the effects on reading performance using hardcopy and two resolutions of monitors, 1664x1200 pixels (120 dpi) vs. 832x600 pixels (60 dpi). Participants read from the same 19-inch monitor using black characters on light background. The subjects viewed the material from a distance of 20 inches (50 cm). In this study, reading from hard copy was reliably faster (200 words per minute versus 180 words per minute).

In terms of online information layout formats, a previous study (Lam, Lam, Liu & Shin, 2000) comparing the reading speed in reading one and three column passage found that the majority of the subjects read the three-column passage faster than the one column passage. Another study investigated user preference between one and three-column format passage and found that the subjects were significantly more satisfied with the three-column format when the passage was displayed on high-resolution screen (800 and 1000 pixels) and found no significant difference with 600 pixel screen (Andreyev & Martynov, 2000).

The present study aims to investigate the effect of information layout on the preference and reading time when the participants read passages on screen or paper. The information layouts tested are the one-column, two-column and three-column formats.

## Experiment

## Hypothesis

This experiment tests the following hypothesis based on the findings from previous research:

- (a) Reading speed increases as the number of column increases.
- (b) Users are significantly slower when reading from screen.
- (c) Users prefer the three-column format compared to the one-column format.

## Participants

This study expands the previous studies by balancing the age group of the participants across the adult life span. Equal number participants from three main age groups participated in the study: 14 young (18-40 years), 14 middle-aged (40-65 years) and 14 seniors (65 years and above). The means age was 50 years (S.D. = 20.44 years).

Participants were divided into two groups (those taking the reading test on the computer and those taking the test on paper). Assignment to the different treatments was random but care was taken that an equal number of participants from each age group took the experiment on screen or on paper.

## Materials

The reading material was obtained from a sample ETS (Educational Testing Service) test and formatted using Hypertext Markup Language (HTML) for presentation on screen. Three different passages (discussing about three different topics) of around 160-165 words each were used. The passages have a readability scale between ten and twelve on the Flesch-Kincaid (Kincaid, Fishburne, Rogers, & Chissom, 1975) grade level score. A random ordering of the three structures (one, two, and three column treatments) was determined prior to the experiment for each participant using a Latin square design. The same pages were then printed on paper using a laser printer to be used for the paper reading experiment. A twelve-point Times New Roman font was used in presenting the text both on screen and on paper.

For the computer experiment, an IBM compatible personal computers with seventeen inch monitors (resolution 1024 X 768 pixels) were used and the text was displayed with a web browser using black characters on a light (white) background. Participants viewed the text from a 50 cm distance. Figure 1 shows an example of a document used in this experiment.

## Procedure

Each participant was first presented with general instructions about the experiment and then was asked to sign the consent form. Then, they were asked to answer a short pre-questionnaire (in the case of users taking the experiment on the computer this included questions about their computer and web use, for those taking the experiment on paper it included questions related to their newspaper/magazine reading frequency).

Participants were then given time to ask clarification questions and finally they were asked to perform a total of three reading tasks. They were instructed to read the passage as fast as possible but as carefully as possible to be able to answer questions related to it after they complete reading. The participants were not told about the hypotheses tested in the study. After completing the reading of each passage, users were asked to answer three basic questions related to what they have just read.

The total time to perform each task was recorded either using an automatic time stamp on the computer or using a stop watch in the case of reading on paper.

After completing his/her last reading task, the participant was asked to record his/her preference of the display format (one, two or three column treatment) and provide a reason for his/her choice.

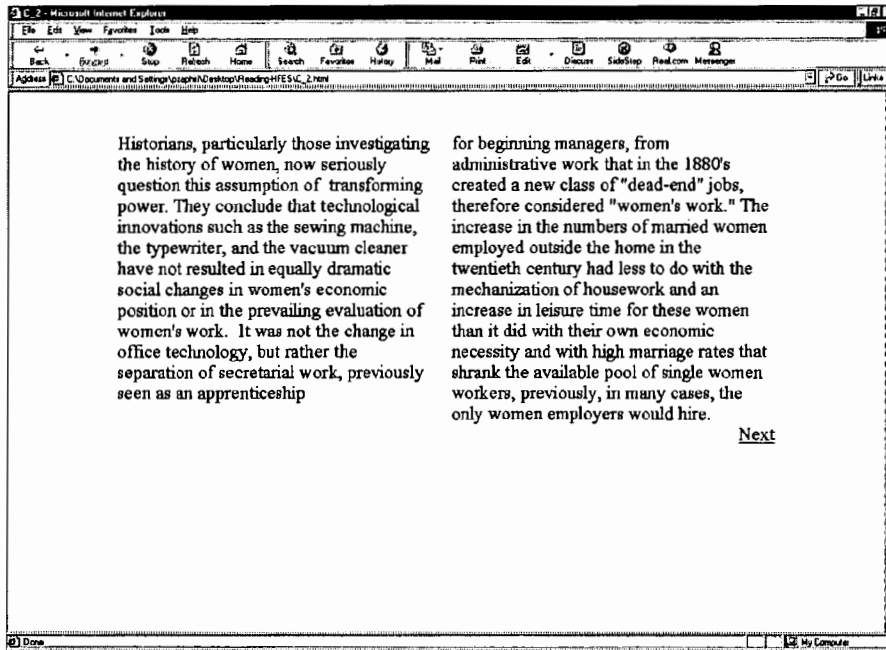


Figure1: Screen shot of a two column text on screen

## Results

### Reading Speed

Table 1 shows the results of reading time (time to complete reading the text in seconds) for all formats.

	1 Column	2 Columns	3 Columns
Computer	63 (24.3)	71 (22.0)	66 (16.8)
Paper	43 (12.8)	51 (18.6)	56 (18.7)
Difference	32 %	28 %	11 %

Table 1: Reading speed (in words per minute) for column 1, 2 and 3 on screen and paper (standard deviation in parenthesis)

Although Table 1 shows that there was reading speed difference between different column formats both while reading on paper or computer screen, to test the first hypothesis, an analysis of variance (ANOVA) needs to be performed. The ANOVA analysis compared the mean reading speed for 1, 2 and 3 columns when reading on paper and on screen. No significant difference was found when reading from computer ( $F(2,60) = 0.78, p > 0.05$ ) among the different column formats, nor when reading on paper ( $F(2,60) = 3.02, p > 0.05$ ). Hence, Hypothesis 1 was not supported.

Visual inspection to Table 1 showed that in general the reading speed was higher when reading on paper across all column formats. However, to test the second hypothesis, another ANOVA analysis was done. Reading on paper was found to be significantly faster than reading on screen when the document is presented in a single ( $F(1,40) = 10.30, p < 0.05$ ) or two column format ( $F(1,40) = 10.03, p < 0.05$ ). No significant difference ( $F(1,40) = 3.01, p > 0.05$ ) was found between reading on screen or on paper for text presented in a three column format. The results of this analysis are shown in Figure 1. Hence, Hypothesis 2 was partially supported.

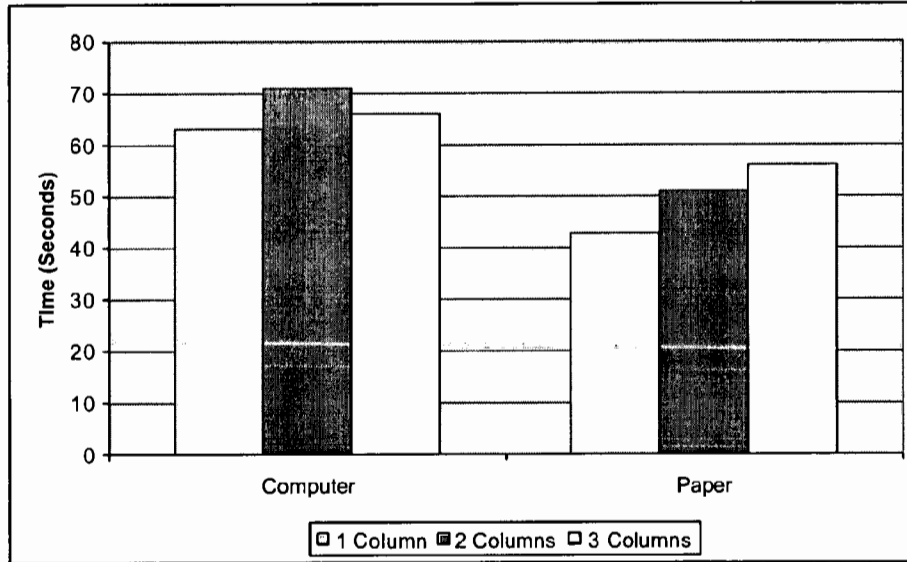


Figure 1: Average reading time results.

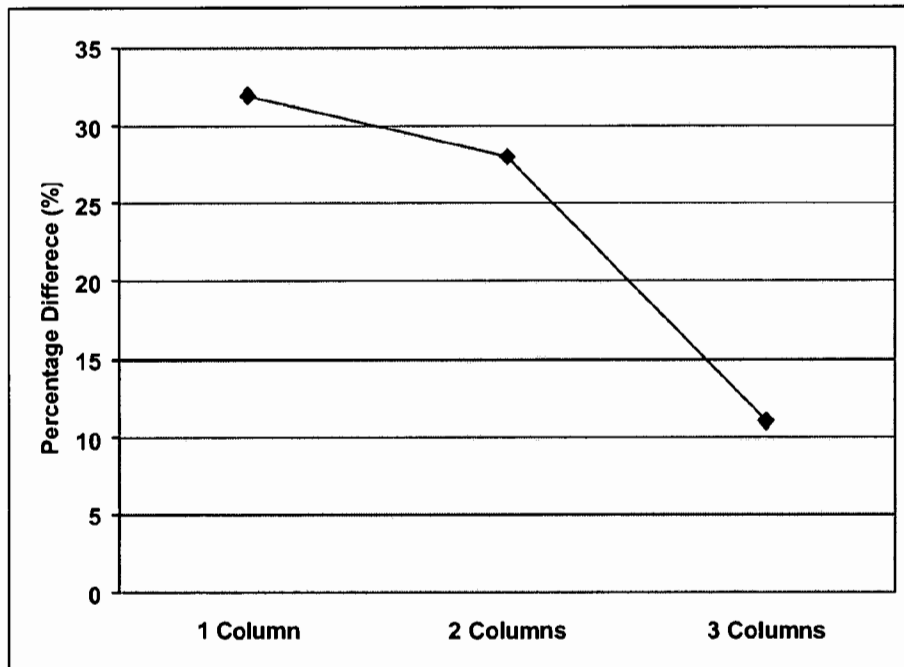


Figure 2: Percentage difference in reading from paper than from screen.

From Table 1 it can be seen that the percentage difference in reading speed diminishes as the number of columns used for displaying the information increases. A 32% difference (faster to read on paper than on screen) when the information is presented in a single column, drops to 11 % (faster to read on paper than on screen) when

the number of columns increases to three. The results of this analysis are shown in Figure 2.

### User Preference

Finally in order to test the last hypothesis, the responses of the user preferences (column 1, 2 or 3) were analyzed. No significant difference was found among user preferences ( $F(1,37) = 0.11, p > 0.05$ ). Hence, Hypothesis 3 was not supported. Table 2 shows these results.

	1 Column	2 Columns	3 Columns
Computer	43%	29%	29%
Paper	33%	39%	28%

**Table 2:** User Preference results

Most of the participants who prefer the one-column format said that the reason was because it didn't require a lot of eye-movements, which they thought would result in disorientation (losing track where they were). Those who prefer two-column emphasized that this layout breaks the information into chunks that are more easily comprehended and it reminds them of a layout of books that they are used to. People who prefer three-column format mentioned that this format flows more easily and it chunks the information into even more highly comprehensible than the two and single column formats. Interestingly, some people wrote the reasoning about why they dislike a certain column-format rather than why they prefer a certain layout. The participants who dislike the one-column format complained that this layout required a lot of eye-movements horizontally. Similarly, those who dislike the two- and three-column formats complained about how narrow the columns were, requiring a lot of eye-movements from line to line and from one column to another.

### Discussions and Conclusion

Overall, the results of this experiment are in agreement with previous studies that showed a 20-30% slower reading speeds when reading on paper than on screen.

The significant difference between reading on paper and screen for one and two column formats may be associated with users' decline of sense of orientation when reading long lines of text (single wide columns) online, most probably resulting in a bigger chance of getting lost and having to re-read the same words.

On the other hand users reading on paper were observed to use different methods to keep track of where they are in terms of reading, some used their finger to point to the words they were reading, others tended to use a pencil or a pen to guide them through their reading path. These methods were observed to be used less often when reading online (although some users did use their mouse pointer to guide them in keeping track with their reading location)

Although we expected (based on previous research) that participants would prefer text presented in three columns than on a single column, there was no significant difference in their preferences. This might be due to the familiarity of users with single column of text than two or three columnar presentation of information.

#### Impact for practitioners

The results of this experiment suggest that designers of online information should keep in mind that reading online is slower than on paper, and they should take steps (such as using bigger font sizes than they would otherwise put in printed materials, high contrast between text and background) to enhance reading speed online.

#### Suggestions for future researchers

Further research on the topic is necessary in order to identify and quantify the different parameters that Muter and Maurutto (1991) pointed out as possible reasons for differences in reading speed between paper and

screen.

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