EFFECTS OF INFORMATION LAYOUT ON READING SPEED: DIFFERENCES BETWEEN PAPER AND MONITOR PRESENTATION

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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, communicating with loved ones) 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
- Visual angle of characters
- Inter-character spacing
- Left justification vs. full justification
- Margins
- Contrast ratio between characters and background
- Intermittent vs. continuous light (Wilkins, 1986)
- Polarity (light characters on a dark background vs. the reverse)
- Emissive vs. reflected light
- Interference from reflections (Daniel & Reinking, 1987)
- Stability (potential flicker, jitter, shimmer, or swim; Stewart, 1979)
- Chromaticity
- Posture of the reader
- Familiarity with the medium
- Absence vs. presence of incidental location cues (Wright and Lickorish, 1984)
- Aspect ratio
- Edge sharpness
- Curvature
- Distortion in corners
- System response time
- Method for text advancement

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 in the future equal the reading speed 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 when reading one and three column passages online found that the majority of the subjects read the three-column passage faster than the one column passage. An other study investigated user preference between one and three-column format passages and found that participants 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 a 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 columns 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. Specifically, equal number of participants from three main age groups participated in this experiment: young (18-40 years), middle-aged (40-65 years) and 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 (presenting information about three different topics – information about the construction of a pipeline, information about women workforce in the early ages of this century, information about bacteria) of around 160-165 words each were used. The passages used had 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, three 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).
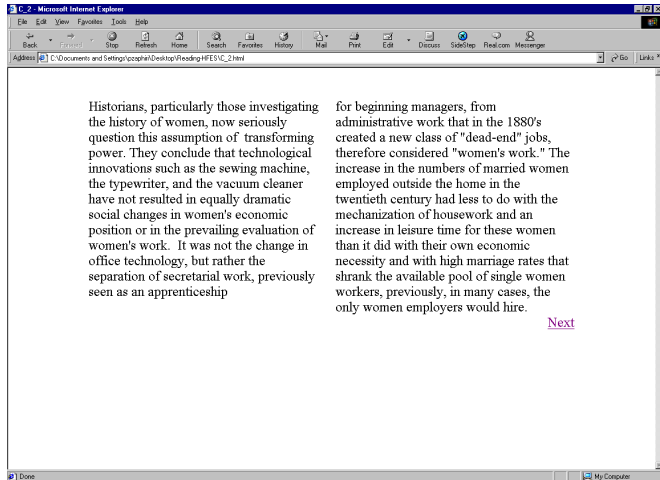

Figure1: Screen shot of a two column text on screen

Participants were then given time to ask clarification questions and finally they were asked to perform a total of three reading tasks (one on each topic and each column treatment used in this experiment). They were instructed to read the passage as fast but also as carefully as possible to be able to answer questions related to it after they completed reading.

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.

Finally, each 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.

RESULTS

Reading Speed

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

Table 1 shows that there were reading speed differences between the three different column formats both while reading on paper or computer screen. To check whether these differences are significant, an analysis of variance (ANOVA) needs to be performed in order to test the first hypothesis that reading speed increases as the number of columns increases. 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 three different column formats, nor when reading on paper $(F(2,60) = 3.02, p > 0.05)$. Hence, Hypothesis 1 was not supported.

Table 1: Reading time for column 1, 2 and 3 on screen and paper (standard deviation in parenthesis)

	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 %

Visual inspection of Table 1 shows that in general the reading speed was higher when reading on paper across all column formats. However, to test the second hypothesis that users are significantly slower when reading from screen, 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 2. Hence, Hypothesis 2 was partially supported.

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 3.
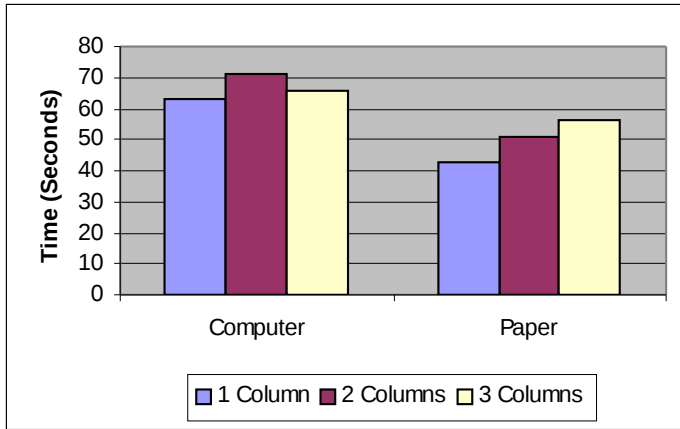
Figure 2: Average reading time results.

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 (users prefer the three-column format compared to the one-column format) was not supported. Table 2 shows these results.
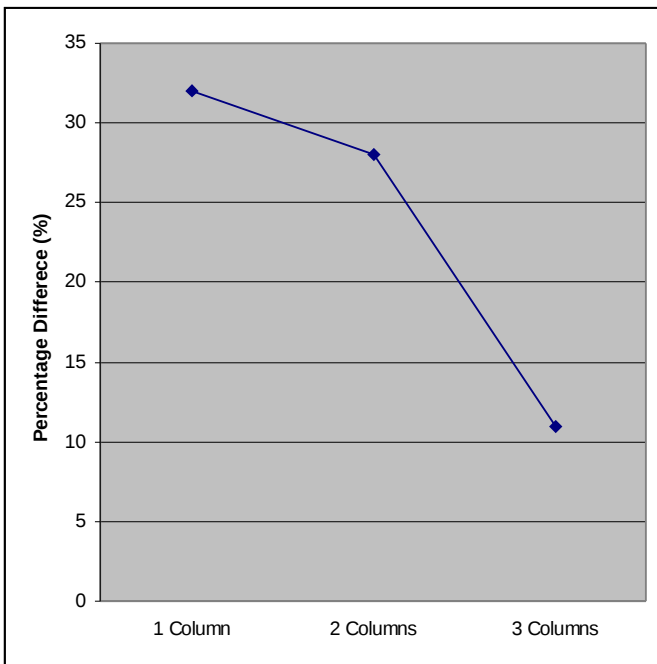

Figure 2: Percentage difference in reading from paper than from screen.

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 (loosing track as to where they were in terms of reading the passage).

Those who preferred the two-column format emphasized that this layout breaks the information into chunks that are more easily comprehended and reminds them of the layout of books that they are more familiar with.

Table 2: User Preference results

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

Finally, People who preferred the three-column format mentioned that this flows more easily and it chunks the information into even more highly comprehensible and easy to follow 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 CONCLUSIONS

Overall, the results of this experiment are in agreement with previous studies that showed that participants took 20-30% more time when reading on paper than when reading 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 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 (using bigger font sizes, high contrast between text and background) to enhance reading speed online. Even though no qualitative significant difference among the three column formats was found in terms of reading speed, subjective ratings show a user preference towards one column formats.

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. Also the aging related dimension of reading speed can be further examined and quantified.

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