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Reasons Why We Prefer Reading on Paper Rather Than Displays: Studies for Seeking Paper-like Readability on Electronic Paper

Junko Imai
Course of Electro Photo Optics, Graduate School of Engineering, Tokai University, 1117 Kitakaname, Hiratsuka-shi, Kanagawa-ken, 259-1292 Japan

Makoto Omodani▲
Course of Electro Photo Optics, Graduate School of Engineering, Tokai University, 1117 Kitakaname, Hiratsuka-shi, Kanagawa-ken, 259-1292 Japan and Department of Optical and Imaging Science & Technology, School of Engineering, Tokai University, 1117 Kitakaname, Hiratsuka-shi, Kanagawa-ken, 259-1292, Japan
E-mail: omodani@keyaki.cc.u-tokai.ac.jp

Abstract. *This study aims to clarify the factors behind the readability of paper documents; the clarification is intended to yield good guidelines for realizing truly readable Electronic Paper. Proofreading tasks were conducted under various reading conditions; display area was varied from 1/2 page to 4 pages on the screens. Proofreading performance is shown to increase with the number of pages simultaneously provided. This result agrees with our general impression that it is difficult to complete proofreading tasks on computer screens, which usually provide less than one page. The disadvantages of small display areas were confirmed regardless of the subjects' ages. Helpful guidelines for designing readable Electronic Paper were suggested by our study. © 2008 Society for Imaging Science and Technology.*
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INTRODUCTION

The development of Electronic Paper, which has the merits of both paper and electronic displays, is being eagerly pursued.[1,2] Reading on paper is still generally preferred over reading on displays despite the rapid progress in electronic display technologies. This study aims to clarify the factors behind the readability of paper,[3–6] and so identify good guidelines for realizing truly readable Electronic Paper. We have already suggested that scrolling, which is a popular reading style on displays, is a key factor reducing the readability of displays.[7] This hypothesis is now expanded into our next supposition that the simultaneous display of multiple pages, which is common with printed documents, is one key to the superior readability of paper. This study confirms our hypotheses by proofreading tasks on various display areas; performances and preferences are evaluated for each style. Furthermore, the dependency of the results on the reader's age is also evaluated in this study. This is done to ascertain the general belief that the younger generation is accustomed to doing tasks on small screen areas as in video games.

EXPERIMENTAL METHODS

Proofreading tasks for a four page Japanese document were conducted using four different display modes as follows:

(a) All four pages shown simultaneously using two screens.
(b) Two pages shown simultaneously using a single screen; page flipping is needed to read all pages.
(c) Single page shown; three page flips needed to read all pages.
(d) Half page shown; scrolling is necessary to read all pages.

Summary and appearance of these four modes are shown in Table I and Figure 1, respectively.

Two experiments with different proofreading tasks were performed as shown in Table II. The task in Experiment (A) was a kind of simple spellcheck.[8] A certain number of Kanji characters were misused and some necessary Kana characters were omitted from the texts. Subjects were asked to find the

Table I. Display modes used in proofreading tasks.

Display area	No. of screens	Paging method
(a) 4 pages	2 (2 pages per screen)	None
(b) 2 pages	1	Click
(c) 1 page	1	Click
(d) 1/2 page	1	Scroll

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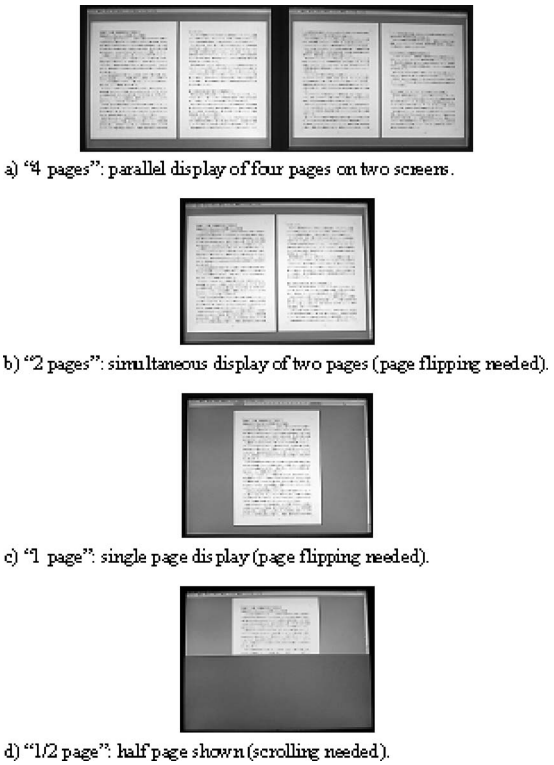

Figure 1. Four display modes. (a) "4 pages": parallel display of four pages on two screens. (b) "2 pages": simultaneous display of two pages (page flipping needed). (c) "1 page": single page display (page flipping needed). (d) "1/2 page": half page shown (scrolling needed).

Table II. Two tasks used in the experiments.

Experiment	Prepared errors	Control	Reference between pages
A (Simple)	Misused and omitted characters	Read through only once	Useless
B (Complex)	Inconsistent wording	No restriction of rereading	Useful

problems and write them down on an answer sheet; the total number of errors was unknown to the subjects. They were allowed to read through the article only once. Figure 2 shows typical examples of task scene, prepared errors, and answers.

A more complex task, checking the consistency of wording, was used in Experiment (B). Subjects were ordered to discover the words in an article that should be replaced in order to keep word consistency and write them down on an answer sheet; the total number of words to be corrected was unknown to the subjects. They were allowed to read the articles any number of times until they were confident that they had completed the task.

The impact of the multi-page display was expected to be seen strongly in Experiment (B) since it is assumed that cross referencing of pages is necessary to ensure word consistency in the four page length of the document. Experiment (A) was intended to check the existence of impact of

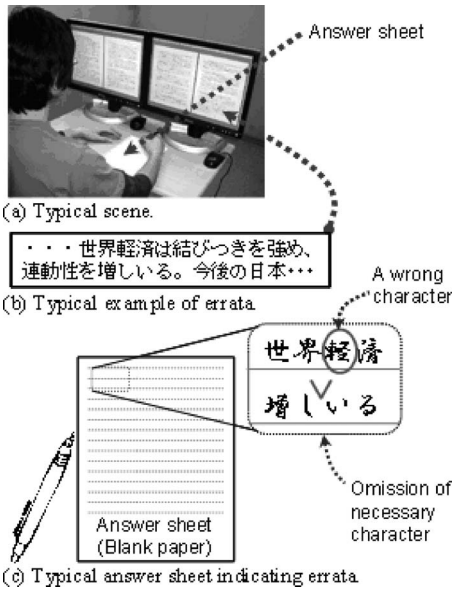

Figure 2. Typical scene and answer in experiment (A). (a) Typical scene. (b) Typical example of errata. (c) Typical answer sheet indicating errata.

Table III. Experimental conditions.

Items		Specs
Environments	Place	Sound-proof room (No glare)
	Illumination	500 lx (on the desk plane)
Screen	Size	20.1 in.: UXGA (TFT display)
	Format	Horizontal writing with portrait format B5 size (30 characters× 30 lines in a page)
	Font	MS Ming style, 12 pt

the display mode on a simple error discovery task. Most proofreading jobs require both tasks to be conducted. Our experiments were designed to evaluate the impact of display mode on each proofreading task independently.

Table III shows the common conditions used in both experiments. One or two sets of liquid crystal displays of 20.1 in. were set on a desk in a sound-proof room for subjects. Japanese texts of horizontal writing with portrait format of B5 size were displayed with 12 pt font on the liquid crystal displays. Error discovery rates and time taken were measured for the proofreading task in these conditions as objective measure.

Given the context of the system as a tool for proofreading, two different aspects of the subjective appeal of each display mode ("Easiness" and "Liking") were assessed by each subject using five rank preference scores. Expressions for the three major scores, 1, 3, and 5, are summarized in Table IV. Table V describes the subjects who participated in each experiment. The order in which the four display modes presented was changed for each subject in order to eliminate the impact of the order of experiencing each display mode.

Table IV. Explanations of the subjective evaluation scores.

Score	Impression of the condition for proofreading	
	(i) Easiness of proofreading	(ii) Liking
5	Easy	Like
3	Middle	Middle
1	Difficult	Dislike

Table V. Subjects engaged in the proofreading tasks.

Experiment	Total	Specs	
A, B (both)	16 people	"Young"	8 students (early 20s)
		"Senior"	8 people (older than 40)

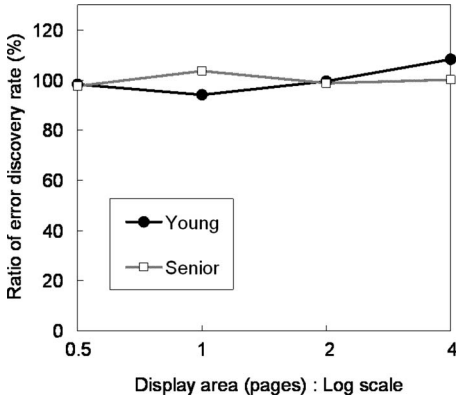

Figure 3. Averaged ratios of error discovery rates [simple task].

EXPERIMENTAL RESULTS

Experiment (A) [Simple Task]

For the evaluation of the error discovery rate and the time taken, normalized results for each subject ({a measured value on each display mode} / {an average of all the measured values for each person on all the four display modes}) were used instead of raw measured values in calculating the averaged values of all subjects, in order to avoid the influence of any difference in ability among the subjects. Figures 3 and 4 show averaged ratios of the error discovery rates and the time taken, respectively. Figures 5 and 6 show averaged subjective evaluation scores on "Easiness of proofreading" and "Liking," respectively. In these figures, "Senior" indicates averaged results for the eight subjects older than 40 and "Young" indicates the averaged results for the eight subjects in their early 20s.

Figure 3 shows that the error discovery rates were almost independent of the page number. The subjective evaluations showed a clear preference, common to both groups, for "1 page;" see Figures 5 and 6. The clear drop in score for

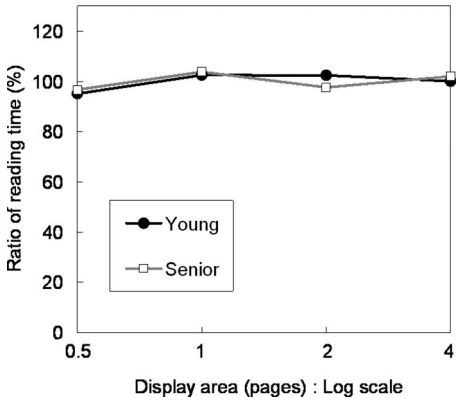

Figure 4. Averaged ratios of time taken [simple task].

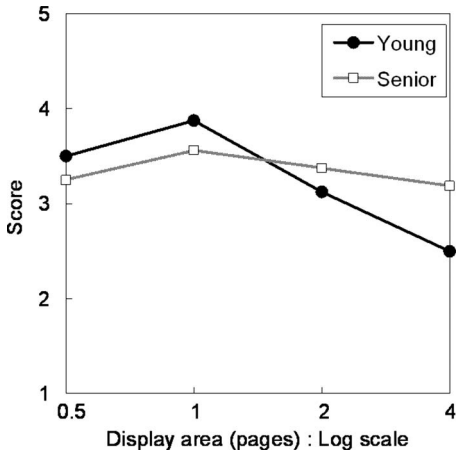

Figure 5. Averaged score of subjective evaluation: "Easiness of proofreading" [simple task].

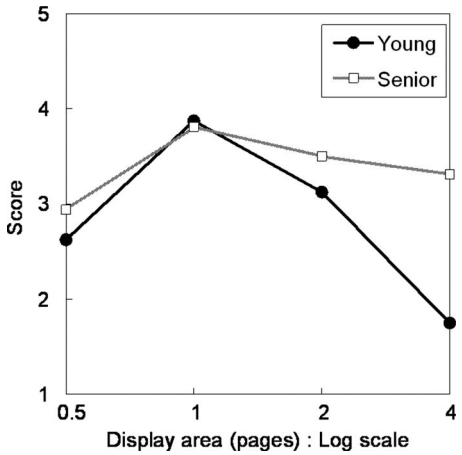

Figure 6. Averaged score of subjective evaluation: "Liking" [simple task].

"1/2 page" should be noted. The unexpectedly low subjective score for "4 pages" was considered to be related to the comments made by most subjects that the "4 pages" mode was too wide for this kind of proofreading task. It is conceivable that the subjects might have felt uncomfortable since the two screens surrounded the subject like a wide wall. This dislike might be mitigated by replacing the vertical

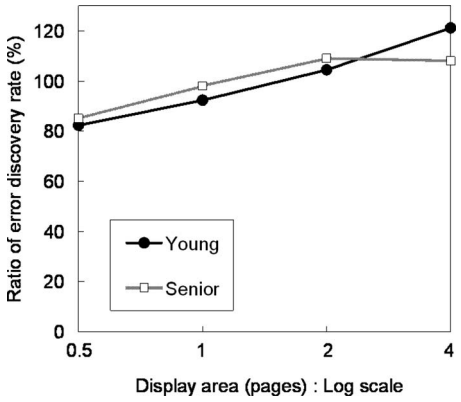

Figure 7. Averaged ratios of error discovery rates [complex task].

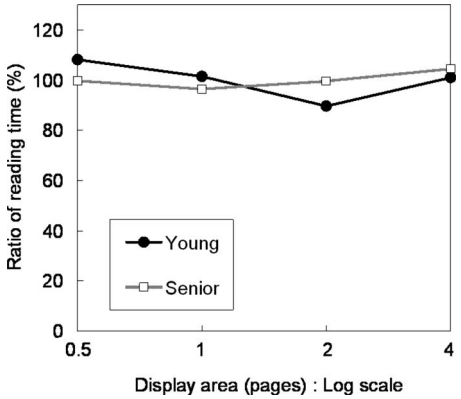

Figure 8. Averaged ratios of time taken [complex task].

screens with thin display sheets that can be laid down on the desk. This supposition will be confirmed in future work.

Experiment (B) [Complex Task]

Figures 7 and 8 show averaged ratios of the error discovery rates and the time taken, respectively. The error discovery rates by "Young" subjects showed a clear increase with the page number, from one-half to four pages; see Figure 7. It should be noted that the ratio of "one-half page" to "four pages" is only 67%; this means that a 33 % reduction is shown for "one-half page" when the discovery rate is normalized by the rate for "4 pages." The error discovery rates by "Senior" subjects showed a similar trend to that of the "Young" subjects except that the error discovery rates saturated for displays ranging in size from two to four pages. The time taken for the task decreased as the page number increased up to two pages for "Young" and up to one page for "Senior;" see Figure 8.

Figure 9 shows the correlation between the error discovery rates and the time taken. Here we define the efficiency of the proofreading task as the error discovery rate divided by the time taken. This efficiency is indicated in Fig. 9 by the slopes of the straight lines fitted to each set of data. Figure 10 shows the dependence of the calculated efficiencies on the display area. The efficiencies clearly increase with the display area except that the efficiency of "Senior" subjects showed a mild peak at "two pages."

Figures 11 and 12 show averaged subjective evaluation

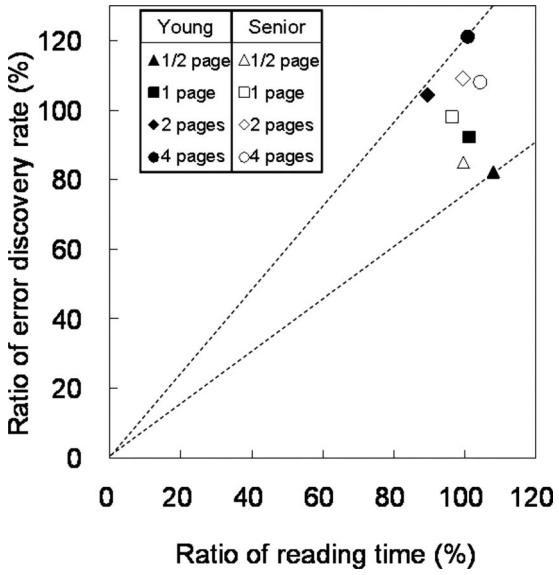

Figure 9. Correlation between the error discovery rates and the time taken [complex task].

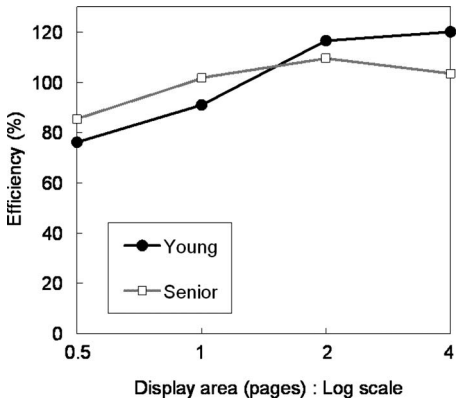

Figure 10. Averaged efficiencies: the error discovery rate divided by the time taken [complex task].

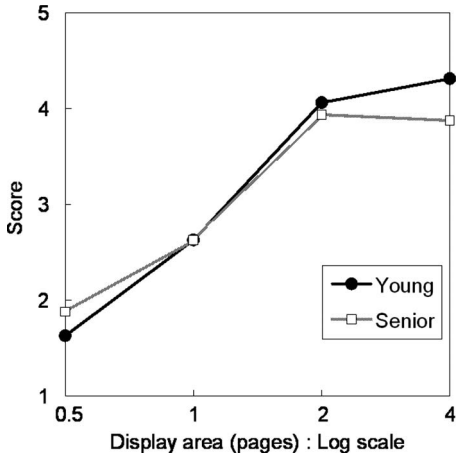

Figure 11. Averaged score of subjective evaluation: "Easiness of proofreading" [complex task].

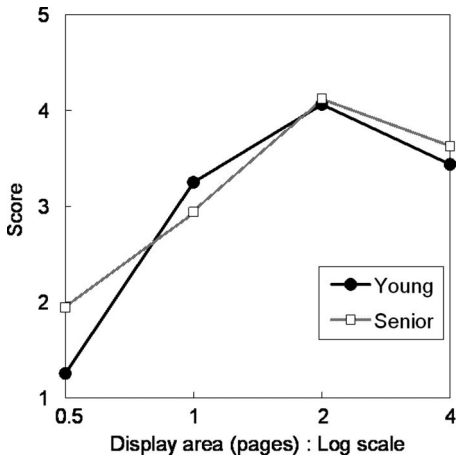

Figure 12. Averaged score of subjective evaluation: "Liking" [complex task].

scores for "Easiness of proofreading" and "Liking," respectively. Increases were also clearly shown in the subjective evaluations for "Easiness of proofreading" as the page number increased from one-half to four; see Fig. 11. This rise almost saturates at two pages. It is reasonable that this saturation in the subjective evaluations corresponds to the saturation in the measured efficiency shown in Fig. 10. The score of "Liking" also increased with page number from one-half to two; see Fig. 12. However, the score for "four pages" was lower than that for "two pages"; this deterioration may be related to the comments of the subjects that the "four page" mode was too wide for comfortable viewing.

These results confirm the clear advantage offered by the simultaneous display of multiple pages, at least two, for rather complicated tasks that demand cross referencing of the whole article. It should be noted that, in Experiment (B), smaller display areas were disadvantageous for proofreading regardless of the user's age; this result is contrary to the general belief that the younger generation is accustomed to, and good at, doing tasks on small screen areas, e.g., as in video games. Experiment (B) showed, as expected, a far stronger impact of multi-page display than evidenced in Experiment (A); cross referencing of pages is not thought to be necessary for the simple spell checks conducted in Experiment (A).

CONCLUSIONS

Objective and subjective evaluations of various display modes for performing proofreading tasks were conducted to clarify guidelines for realizing truly readable Electronic Paper. Notable results indicated by our experiments are as follows:

(1) For complicated tasks that demand cross referencing of the whole article, increasing the number of pages shown, from one-half to two pages, simultaneously increases objective performance and subjective preference.
(2) For simple tasks such as spell checking, the score of subjective impression peaked at "one page," although rather flat results were shown in terms of the objective performances with almost no dependence on the display area.
(3) The disadvantages of smaller display areas were confirmed for both generations studied.

These results agree with our general impression that it is difficult to complete proofreading tasks on computer screens, which usually provide less than one page. This agreement can be expected to hold for more general tasks on a computer screen. An essential problem of reading on conventional displays is suggested by these results.

Thus, the following guidelines for Electronic Paper are suggested by our study:

(1) Display area must cover one whole page (no scrolling needed).
(2) It is desirable to use simultaneous display of multiple pages for finishing complicated tasks.

A comfortable and appealing Electronic Paper system is expected to be realized by following these guidelines.

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