Reason Why We Prefer Reading on Paper rather than Displays − An approach to the ideal design of readable Electronic Paper −

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Abstract

This study aims to clarify the factors behind readability of paper documents; the clarification is intended to yield good guidelines for realizing truly readable Electronic Paper. Proofing tasks were prepared on various reading conditions; display area was varied from 1/2 page to 4 pages on the screens. Performance is shown to increase with the number of pages simultaneously provided. This result agrees to our general impression that we generally feel that it is difficult to complete proofing tasks on a computer screen, which usually provides less than one page.

1. 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], the clarified factors will suggest good guidelines to realize 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 using proofreading tasks on various display areas; performances and preferences should be 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.

2. Experimental Methods

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

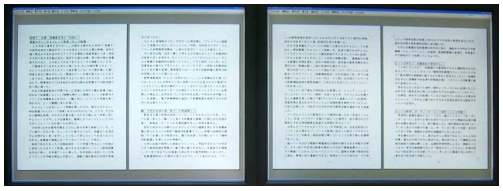
a) All four pages shown simultaneously using two screens.
b) Two pages shown simultaneously using a single screen;
page flipping is needed to read all pages.
c) Single page shown;
three page flips needed to read all pages.
d) Half page shown;
scrolling is necessary to read all pages.

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

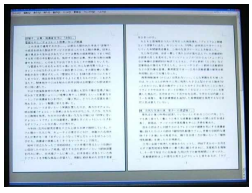
Two experiments with different proofing tasks were performed as shown in Table 2. The task in Experiment (A) was

Table 1. Display modes used in proofreading tasks

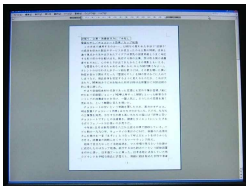
Display area	Number of screens	Paging method
a) 4 pages	2 (2 pages per screen)	None
b) 2 page	1	Click
c) 1 page	1	Click
d) 1/2 page	1	Scroll



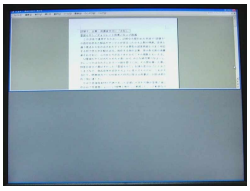
a) “4 pages”: parallel show of four pages using two screens



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)

Figure 1. *Four display modes*

a kind of simple spell-check.[8] A certain number of Kanji characters were misused and some necessary Kana characters were omitted from the texts. Subjects were ordered to find the problems, and write them down on an answer sheet; the total number of errors was unknown for 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 find 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 word to be corrected was unknown for the subjects. They were allowed to read the articles any number of times till they were confident that they had completed the task.

The impact of 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 for the four pages. Experiment (A) was intended to check existence of impact of 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 3 shows the common conditions used in both experiments. Error discovery rates and time taken were measured as objective measure. Subjective impressions on each display mode were provided by each subject using five rank preference scores. Expressions for the three major scores, 1, 3, and 5, are summarized in Table 4. Table 5 details the subjects who participated in each experiment.

Table 2. Two tasks used in the experiments

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

Table 3. Experimental conditions

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

Table 4. Explanations of the major subjective evaluation scores

Score	Impression of the condition for proofreading
5	Easy
3	Middle
1	Difficult

Table 5. Subjects engaged in the proofreading tasks

Experiment	Total	Specs	
A	16 people	"Young"	8 students (early twenties)
		"Senior"	8 people (older than 40)
B	8 people	8 students (early twenties)	

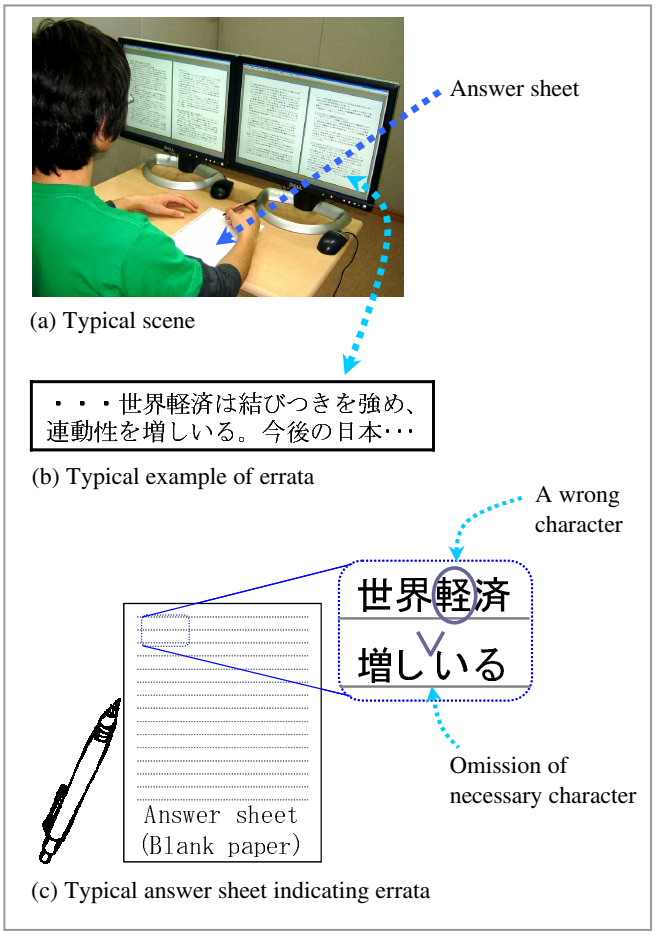


Figure 2. *Typical scene and answer in experiment (A)*

3. Experimental Results

3.1 Experiment (A) [Simple task]

Figures 3 and 4 show averages of the error discovery rates and the time taken, respectively. Figure 5 shows the correlation between the error discovery rates and the time taken. Figure 6 shows averaged subjective evaluation scores. In these figures, "Senior" indicates averaged results of the 8 subjects older than 40 and "Young" indicates averaged of results of the 8 subjects in their early twenties.

Figure 3 shows that the error discovery rates were almost independent on the page number; the only obvious trend was the superior performance of the senior group. The notable trend, common to both groups of subjects, in Figure 4, was the increase of time taken when the display area was changed from 1/2 page to 1 page.

A fairly strong correlation is shown in Figure 5 between the error discovery rates and the time taken for the senior group. This correlation indicated that the increase in the error discovery rates was brought by the increase of 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 Figure 5 by the slope of the straight lines fitted the plots for each group of subjects.

The subjective evaluations showed a clear preference, common to both groups, for "1 page", see Figure 6. The clear drop in score for "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 page" mode was too wide for this kind of simple task. It is supposed that only uncomfortable impression might be brought to the subjects by the combination of two screens surrounding a subject like a wide wall, if no special advantage for discovering simple errors was felt there. It is expected that this kind of decrease in subjective impression for multiple pages may not be shown in the case of parallel usage of thin display medium which can be laid down on a desk. This supposition is now left to be confirmed by our future work.

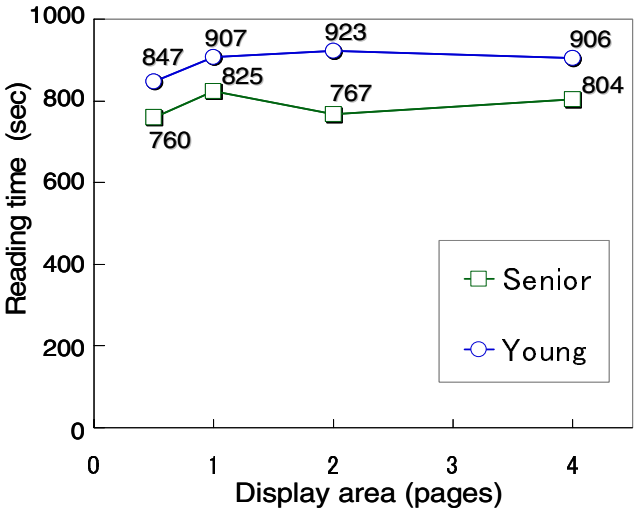


Figure 4. *Averaged time taken [simple task]*

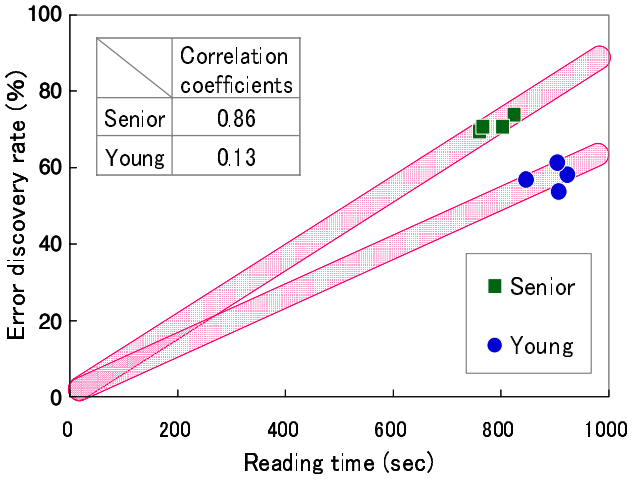


Figure 5. *Correlation between the error discovery rates and the time taken [simple task]*

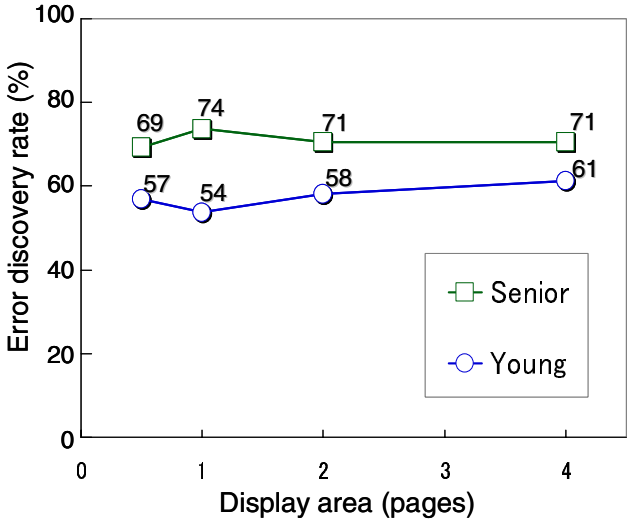


Figure 3. *Averaged error discovery rates [simple task]*

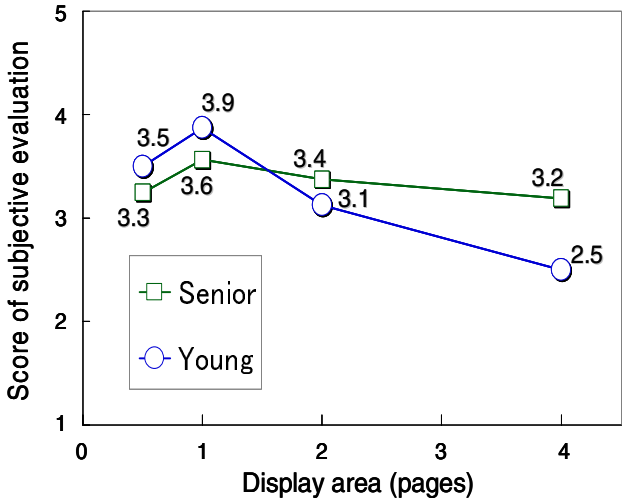


Figure 6. *Averaged score of subjective evaluation [simple task]*

3.2 Experiment (B) [Complex task]

Averaged results of the 8 subjects in their early twenties for the complex task are shown in Figures 7-10. The error discovery rates showed a clear increase with the page number, from 1/2 to 4 pages, see Figure 7. It should be noted that the ratio of "1/2 page" to "4 pages" is only 67%; it means that 33 % reduction is shown for "1/2 page" when the discovery rate is normalized by the rate for "4 pages".

The time taken decreased as the page number increased up to 2 pages, see Figure 8. The combination of the increase in error discovery rate and the decrease in time taken raised the efficiency of the proofreading task, as shown in Figure 9. It is to be noted that the plots for "4 pages" and "2 pages" fall on the same line. This means that the increase of error discovery rate from "2 pages" to "4 pages" resulted from the increase of the reading time. The reason is left as an open question why the reading time for "4 pages" increased. A possible reason was that the subjects were more deeply absorbed in their task at "4 pages" condition, where they were not disturbed by the demand of page flipping.

Increasing advantages were also clearly shown in the subjective evaluations as page number increased from 1/2 to 4, see Figure 10. This rise almost saturates at 2 pages. It is reasonable that this saturation in the subjective evaluations corresponds to the saturation in efficiency shown in Figure 9.

These results confirm the clear advantage offered by the simultaneous display of multiple pages, at least 2, for rather complicated tasks that demand cross referencing of the whole article.

Experiment (B) showed, as expected, far stronger impact of multi-page display than that in Experiment (A); cross referencing of pages was not supposed to be necessary for simple spell check in Experiment (A).

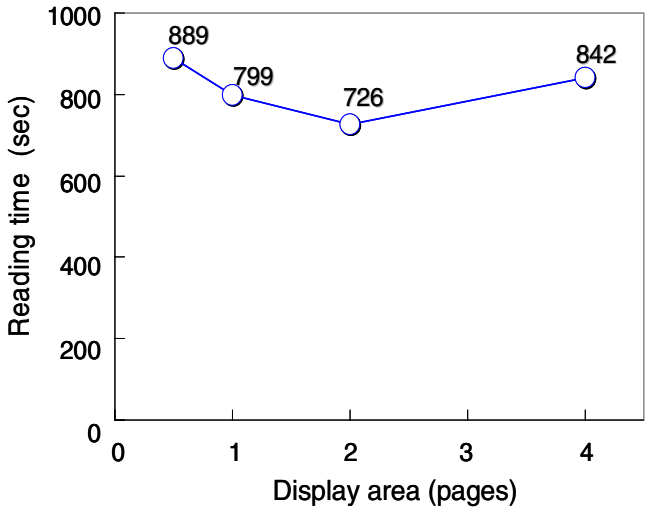


Figure 8. *Averaged time taken [complex task]*

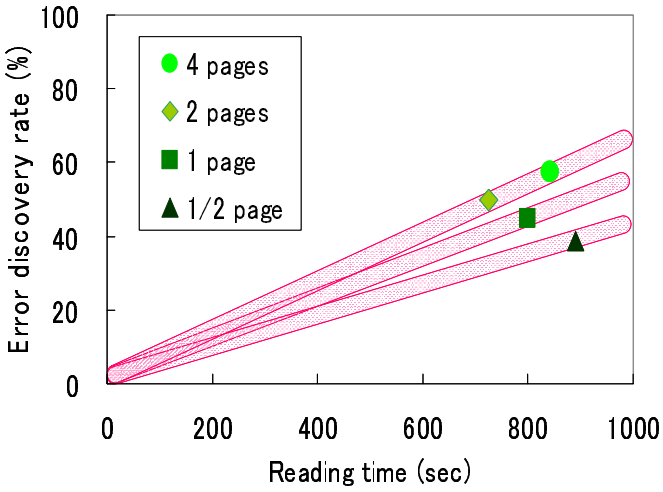


Figure 9. *Correlation between the error discovery rates and the time taken [complex task]*

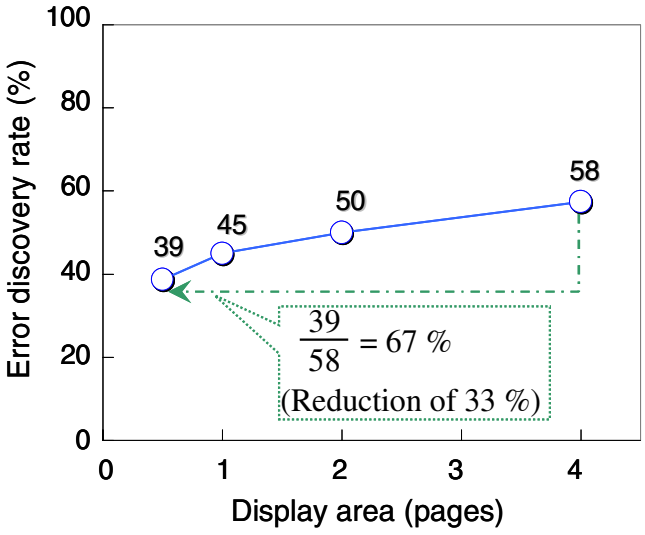


Figure 7. *Averaged error discovery rates [complex task]*

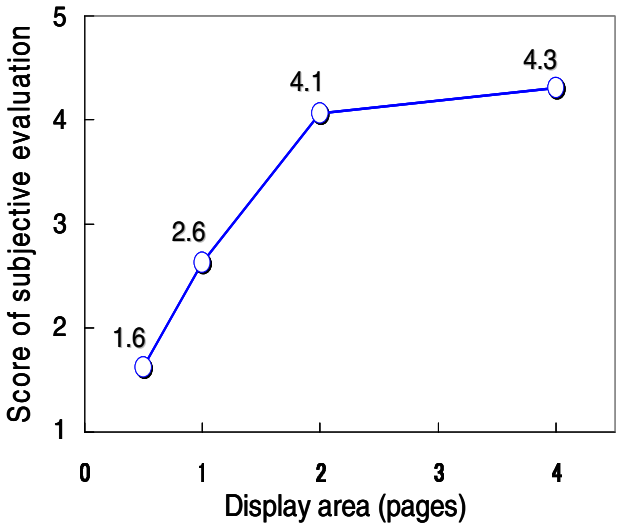


Figure 10. *Averaged score of subjective evaluation [complex task]*

4. Conclusion

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 1/2 to 4 pages, simultaneously increases objective performance and subjective impressions.
2. For simple tasks such as spell checking, a clear drop in score of subjective impression for "1/2 page", which demand scrolling, was indicated although rather flat results were shown in objective performances almost independent on variations of display mode.
3. The above negative assessment of the half page display, which needs scrolling, was confirmed even for the group of younger generation subjects, people who were expected to be accustomed to performing tasks even within reduced screen areas.

These results agree to our general impression that we generally feel that it is difficult to complete proofing tasks on a computer screen, which usually provides less than one page. This agreement is supposed to be expanded into more general tasks on a computer screen. An essential problem of reading on conventional displays was 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) Clear advantage must be brought by simultaneous display of multiple pages especially for rather complicated tasks.

A comfortable circumstance for reading is expected to be realized by the ideal Electronic Paper which follows these guidelines.

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Author Biography

Junko Imai was born in 1983. She received her BE degree in 2006 from Tokai University. She is expected to receive her ME degree from the graduate school of Tokai University in 2008. She is now engaged in a study of Readability as a Target of Electronic Paper.