A Study on Readability as a Goal of Electronic Paper - Effects of Media Handling Styles -

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Abstract

The development of electronic paper, which has the merits of both paper and electronic displays, is being eagerly pursued. This study aims to clarify the factors of readability which is naturally realized by paper; clarified factors will yield good guidelines for realizing readable electronic paper. Our expectation is that reading style is an important factor determining readability. We evaluate the reading performance of three medium handling styles (vertical, horizontal, hand-held) using current electronic books (LIBRIe, ΣBook) and paper documents. Test results show, for both types of electronic books, that the "hand-held" style is superior in terms of lower fatigue and better readability. It is suggested that the readability of electronic displays can be enhanced by making them compact and permitting the hand-held reading style.

Introduction

Electronic paper, which should provide the advantages of both paper and electronic displays, is a prime research topic.[1,2] This study aims to clarify the factors of readability with regard to paper; these factors will yield good suggestions for realizing readable electronic paper. Several reports presented on the factors of readability have examined medium angle,[3] medium form,[4] contrast,[5] lighting condition[6] etc. However, it is not clear how to assess these factors. We are attempting to clarify the causes of the difference in fatigue levels seen for two kinds of media: paper and electronic displays (displays hereafter). One possible cause is the difference in reading styles. “Freehand holding” is a popular way of reading text on paper, and this reading style is totally different from the fixed reading style provided by displays on desks.

We have already reported a comparison of readability and fatigue level of reading tasks on paper and on displays. We have confirmed that freehand holding increases readability and reduces fatigue levels especially for displays.[7-9] This study aims to reconfirm that the "hand-held" condition is advantageous for reducing fatigue and enhancing readability. Reading performances were evaluated for different medium handling styles using current electronic books (LIBRIe, ΣBook) and paper. The Analytic Hierarchy Process* (AHP) was used for this subjective evaluation.[10,11]

Experiments

Experimental Method

Experiments were carried out in order to evaluate fatigue levels (eyes or body) and readability under various reading styles using current electronic books (LIBRIe, Σbook) and paper. Three different reading styles were examined: vertical (the medium was set on a desk (A)), horizontal (the medium was laid on a desk (B)), and hand-held (C).

Figure 1 shows the reading scenes as combinations of the three reading styles and the three media. The subjects were presented with material from a Japanese novel and the volume of text read in a 30 minute period was measured. Fatigue levels were assessed from the subjects' responses collected just after each reading task. The tasks were spaced at 15 minute intervals.

Table 1 lists the specifications of the three media. Table 2 shows experimental conditions. Table 3 gives the instructions provided to the subjects.

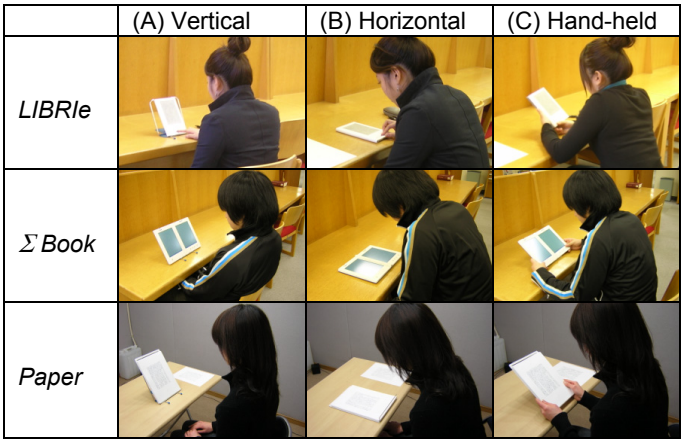

Figure 1. Scenes of Evaluations

Table 1: Media Used in Evaluations

Mediums	Weight	Picture size
LIBRIe	300 g	6 inch : SVGA
Σ Book	560 g	7.2 inch : XGA
Paper	360 g	B5 size (lengthways) 80 sheets on board

Table 2: Evaluation Conditions

	LIBRIe	Σ Book	Paper
Number of subjects	6	6	6
Subjects	Male and female students, Age: 18-24		
Place	Sound-proof room		
Illumination	800 lx (on the desk plane)		

Table 3: Instructions to Subjects

Reading styles	Direction for subjects
Horizontal	Put a medium against the stand on the desk. You may initially adjust the angle as you like
Vertical	Place a medium flat on the desk.
Hand-held	Hold a medium in your hand

Evaluations Method

Subjects were requested to answer three evaluation items:

1. eye fatigue,
2. body fatigue (except eyes),
3. readability.

First, subjects were asked to rate the importance of the three evaluation items: (1) to (3). Next, the subjects were presented with one medium and used it in the three reading styles: A to C. Last, subjects were requested to evaluate the effect of the three reading styles.

The score of each subject was calculated by multiplying the following two elements: their initial importance rating given to the three evaluation items (1) to (3), and evaluated scores of the three evaluation items. Final score for each reading condition was gained by averaging the scores of each subject.

All the evaluations were carried out using the method of comparing pairs of reading styles. Evaluation result for each reading style was calculated using the three sets of comparison results. Figure 2 shows the evaluation scale used in all comparisons between each pair of evaluation items and each pair of reading styles. Names of objects to be evaluated are written at the ends of the scale: i.e. the positions of "object 1" and "object 2" in Fig. 2.

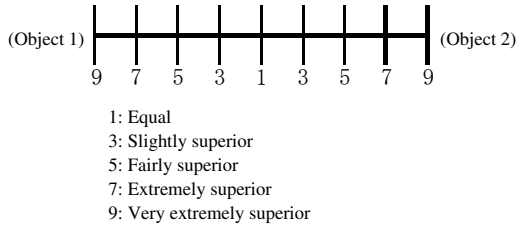

Figure 2. Scale and indexes used in evaluations

A typical example of evaluation sequence is as follows.

Step 1: Rating to Evaluation Items

Table 4 shows a typical answer provided by a subject and used for rating evaluation items. The subject was required to answer only three values in the table, the other values were determined from the three entered values automatically. Table 4 was then transformed into a 3 by 3 matrix, see Fig. 3. Eigenvectors were calculated from the matrix. These eigenvectors indicate the subject's own rating for three evaluation items.

The rating of this subject was thus calculated as follows: [eye fatigue, body fatigue, readability] = [0.28, 0.33, 0.39]. This result shows that this subject gave most importance to readability.

Table 4: A Typical Answer

	Eye Fatigue	Body fatigue	Readability
Eye fatigue	(1)	3	(1/7)
Body fatigue	(1/3)	(1)	3
Readability	7	(1/3)	(1)

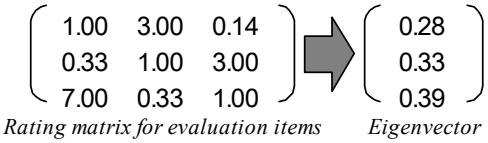

Figure 3. Calculation of eigenvectors with a 3 by 3 rating matrix for evaluation items

Step 2: Evaluation of Reading Styles

Subjects were instructed to read the material in the three reading styles, and then compare the three pairs of three reading styles. The evaluation process of Fig. 2 was applied to their answer. Table 5 shows a typical evaluation result for the three reading styles. Table 5 was transformed into three matrixes; eigenvectors were calculated as shown in Fig. 4.

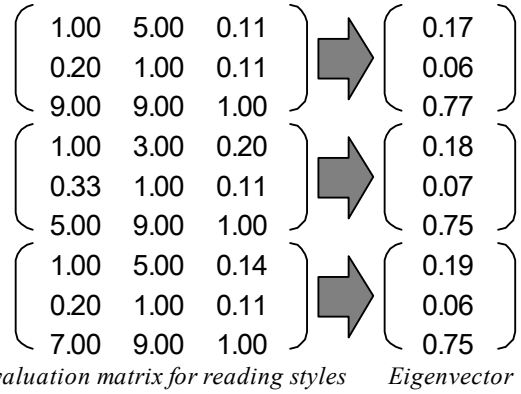

Figure 4. Calculation of eigenvectors from a 3 by 3 matrix for evaluation of reading style

Step 3: General Evaluation

The eigenvectors for each evaluation item in each reading style were transformed into a 3 by 3matrix. The general evaluation was obtained by multiplying this matrix by the rating matrix. For this subject, the result of general evaluation is as follows: [vertical, horizontal, hand-held] = [0.18, 0.06, 0.75]. This result indicates that the hand-held style is the most favored reading style for this subject. The same procedure was used for all subjects.

Table 5: A Typical Evaluation Result for the Three Reading Styles

		Vertical	Horizontal	Hand-held
Eye fatigue	**Vertical**	(1)	5	(1/9)
	Horizontal	(1/5)	(1)	(1/9)
	Hand-held	9	9	(1)
		Vertical	*Horizontal*	*Hand-held*
Body fatigue	*Vertical*	(1)	3	(1/5)
	Horizontal	(1/3)	(1)	(1/9)
	Hand-held	5	9	(1)
		Vertical	*Horizontal*	*Hand-held*
Readability	*Vertical*	(1)	5	(1/7)
	Horizontal	(1/5)	(1)	(1/9)
	Hand-held	7	9	(1)

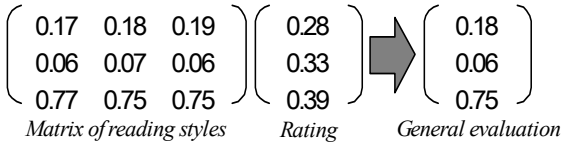

Figure 5. Calculation of general evaluation

Experimental Results

Results at the Electronic Books

Figures 6 and 7 show the evaluation results for the electronic books, LIBRIe and Σbook, respectively. Both yielded the same tendency, the hand-held" style received the highest scores, while "vertical" and "horizontal" styles got quite low scores.

Results for Paper

Figure 8 shows the evaluation results for paper. Differences between the three reading styles are not as large as is true with the electronic books. The hand-held style and the vertical style are slightly superior to the horizontal style.

Discussion

We have confirmed the advantage of hand-held style in the two electronic books examined. This result is reasonable because the "hand-held" style is the most popular way for us to read books. It indicates why people do not like to read on displays.

Paper, on the other hand, showed no significant advantage for the hand-held style The prominent advantage of hand-held style shown at electronic books is reasonable when we consider the viewing angle dependence of readability assumed at the electronic books. Hand-held style is the most easy style for us to adjust the angle of a medium to the best condition to read. The universal readability of papers independent to viewing angle is not supposed to request fine adjustment of its angle; the advantage of hand-held style may not be clear at papers. Thus, we consider that the result at papers indicates the next stage of goal for electronic books: universal readability independent of reading styles.

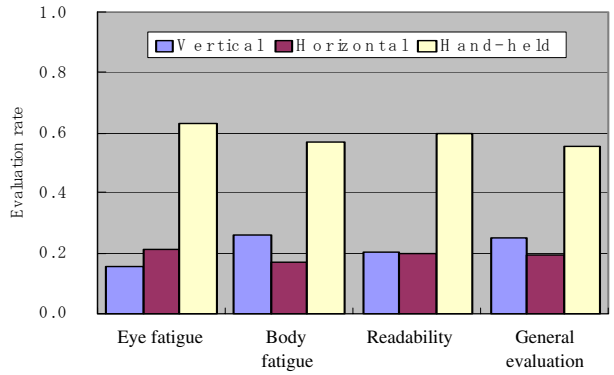

Figure 6. Evaluation results for LIBRIe

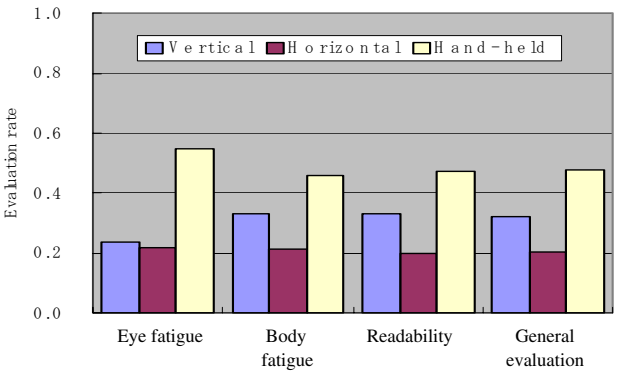

Figure 7. Evaluation results for Σbook

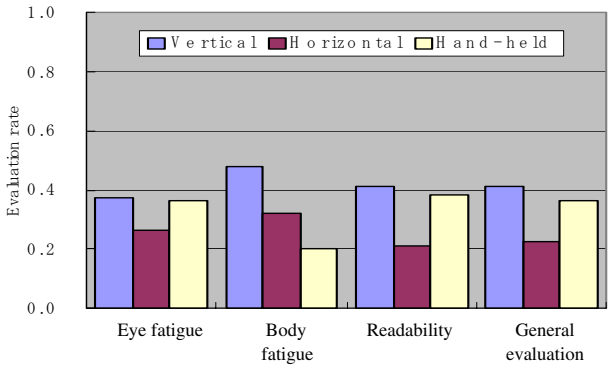

Figure 8. Evaluation results for paper

We also consider that the light weight and compact shape of the two electronic book terminals, which enabled the subjects to use the hand-held reading style, greatly improved their general attractiveness as a reading medium; this is ascribed to their ability to freely alter the viewing angle.

Conclusions

1. We confirmed that the "hand-held" reading style increases readability and reduces fatigue levels for the electronic book units of LIBRIe and ΣBook.

2. It is suggested that compact medium design that allows the hand-held reading style can improve the readability of electronic displays.

References

- Analytic Hierarchy Process (AHP) has been developed by T.L.Saaty (University of Pittsburgh) for a method of decision making to choose the best solution among alternatives. AHP method is based on comparisons between all possible pairs among all the alternatives. Comparisons between several viewpoints for evaluations are the first step of the AHP method; ratings for the viewpoints are gotten in this step. This step is followed by comparisons between all the alternatives. The results of ratings are taken into account for general evaluations at the final step. The comparison performed between pair of alternatives is considered to bring us accurate sensitivity.

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Author Biography

Sho Okano was born in 1982. He received his B.S. degree in 2004 from Tokai University. He is expected to receive his M.S. degree from graduate school of Tokai University in 2006. He is now engaged in a study of Readability as a target of Electronic Paper.