

# Operation efficiency measurements and subjective evaluations for tasks on hardcopy and various displays

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## Abstract

The final goal of this study is to clarify the human-interface requirements for “Digital Paper”. Operation efficiency measurements and subjective evaluation were carried out, as a first step to discern the differences between hardcopy and softcopy for the same tasks. Simple tasks were given to 25 subjects using hardcopy and three displays: CRT, transmission type LCD with back-light, and reflective type LCD. The reflective type LCD was used in two conditions: with desk light, and without desk light. Answer speeds and correct answer rates were measured in an objective evaluation. Questionnaires on viewing ease and degree of fatigue were given to the subjects in a subjective evaluation. The objective evaluation showed only a slight difference between the interface styles; the subjective evaluation showed, on the other hand, the clear superiority of hardcopy to the other display styles.

## Introduction

The need to work on display devices is increasing due, in part, to the growing popularity of the Internet. If the material is voluminous, however, most people prefer to print the text on paper. This tendency is clearly wasteful in terms of time and paper resources. This study aims at clarifying reasons for this tendency<sup>1-3</sup>. Objective and subjective evaluations were carried out on by asking subjects to perform simple tasks on various display devices and hardcopy. The performances achieved in doing the tasks were measured in the objective evaluation. The subjective evaluation was performed by asking questions, after finishing the tasks, on fatigue and comfort during the tasks. Our goal is to clarify the ideal human-interface conditions for optimizing “Digital Paper”<sup>4,5</sup>.

## Experimental

We tested five kinds of medium: Hardcopy, CRT, transmission type LCD, reflective LCD (with desk light), and reflective LCD (without desk light). Reading tasks with simple English questions were given to 25 subjects. Figure 1 shows the working scene. Hardcopy materials were placed on the screen of the LCD as seen in Fig.1.

Figure 2 shows an example of a question sheet. Each subject was instructed to select the Japanese sentences that corresponded most closely to the English sentences. Only 3 minutes were given to each subject for each task; they were asked to match as many English sentences as possible in the 3 minutes.

**Table 1. Experimental conditions**

		(a)	(b)	(c)	(d)	(e)
Medium		CRT	Transmission type LCD	Reflective type LCD with desk light	Reflective type LCD without desk light	Hardcopy
Screen angle		56 degrees above the horizontal plane				
Illumination (lux)	On desktop	440~580	1090 ~ 2130	420~ 580	440~ 580	
	On screen	300~400	2970 ~ 3000	300~400		
Viewing distance (cm)		56~77				
Screen size		175mm x 235mm				



(a) CRT



(b) Transmission type LCD



(c) Reflective type LCD with desk light



(d) Reflective type LCD without desk light



(e) Hardcopy

Figure 1. Working scenes

問題 1	解答群
(1) Shall we go to the lake?	(1) できるだけ、ゆっくり話して下さい。
(2) I couldn't but laugh when he sang.	(2) 君はなんとすてきな靴を買ったのだろう。
(3) You should listen to his advice.	(3) 財布の中にお金が少しありました。
(4) I have nothing to write with.	(4) 湖へいきましょうか。
(5) You feel cold, don't you?	(5) どうぞ、5時まで私を待ってください。
(6) What a nice pair of shoes you bought.	(6) 君は彼の忠告に耳をかすべきだ。
(7) You don't do your homework, did you?	(7) 彼が歌ったとき、私は笑わざるをえなかった。
(8) Get up, or you will miss the train.	(8) 彼はきっと試験に合格するでしょう。
(9) Give me a glass of water.	(9) こんなところで君に会うとは思っていなかった。
(10) You are the last man I expected to meet here.	(10) 私の姉はメアリーと同じくらい上手にピアノが弾けます。
(11) It is said that he is a very kind man.	(11) 君は寒いだろうね。
(12) Junko was the first girl that talked to you.	(12) 淳子は初めてあなたに話しかけた少女でした。
(13) Please speak as slowly as you can.	(13) 起きなさい、さもないと列車に遅れますよ。
(14) The birds flew up higher and higher.	(14) 書くものがありません。
(15) Autumn is suitable not only for study but also for talking exercise.	(15) 鳥はだんだん高く飛び上がった。
(16) My sister can play the piano as well as Mary.	(16) 私に水を一杯下さい。
(17) There was a little money in the purse.	(17) 彼らは必ずしも月曜日にここに来るとは限りません。
(18) I am sure he will succeed in the examination.	(18) あなたは宿題をしませんでしたね。
(19) They don't always come here on Monday.	(19) 秋は勉強だけでなく運動にも適しています。
(20) Please wait for me till five o'clock.	(20) 彼は大変親切な人だそうです。

Figure 2. Example of tasks

An answer sheet was prepared on the desk for the subjects to write the Japanese sentence numbers as the answers. Answer speed and correct answer rate were measured in the objective evaluation. Questionnaires on viewing ease and the degree of fatigue were given to the subjects in the subjective evaluation after finishing all trials. Key conditions of our experiments are listed in Table 1.

The screen size on each medium was set the same by using masks. The order of the questions and test-medium was changed systematically for the purpose of canceling influence of display test order and difference in question difficulty.

A task set was given to each subject that consisted of 6 tests; the 1<sup>st</sup> and last tests were given on the same medium. Results for the second to last tests were taken into account in the subjective measurement; the 1<sup>st</sup> test was used for only practice to ensure that the subjects were familiar with the test format.

### Results and Discussion

Figure 3 and Figure 4 shows average reading speeds and correct answer rates for all subjects using the 5 display media. Reading speed was calculated as the percentage of the 20 sentences that were matched in the 3 minutes. Correct answer rate was calculated as the ratio of the number of correct answers to the number of matched sentences in each trial. Figure 4 shows a detailed view of part of Figure 3. Effective reading speed, defined as [(reading speed) x (correct answer rate)] was calculated for each display medium (see Fig.5). The plots show that there is only a slight difference between the five media. The media in decreasing order of performance is reflective type LCD (with desk light), Hardcopy, CRT, transmission type LCD, and reflective type LCD (without desk light).

Subjective evaluation results, which were obtained from the questionnaires filled out by all subjects after finishing all trials, are plotted in Figure 6. The values plotted are the mean values of the answers by all subjects; each subject was asked to choose one of five levels of viewing ease and five levels of fatigue for each medium (see Table 2). Figure 6 indicates that, subjectively, hardcopy provides the greatest readability and least fatigue.

It should be clearly noted that, the superiority of hardcopy work was more strongly seen in the subjective evaluation, not the objective evaluation. This tendency was seen in previous study<sup>1</sup>.

**Table 2. Five answer levels for subjective evaluation**

Level	Readability	Fatigue
5	Very hard to read	Very fatiguing
4	A little hard to read	A little fatiguing
3	Intermediate	Intermediate
2	A little easy to read	A little comfortable
1	Very easy to read	Comfortable

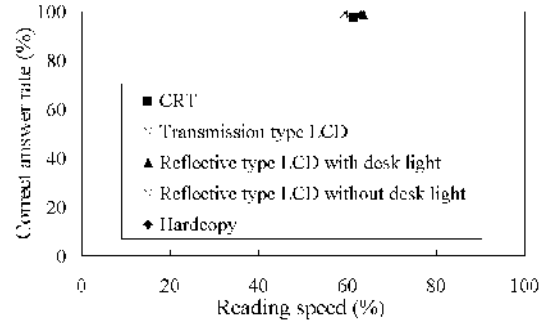


Figure 3. Reading speed and correct answer rate

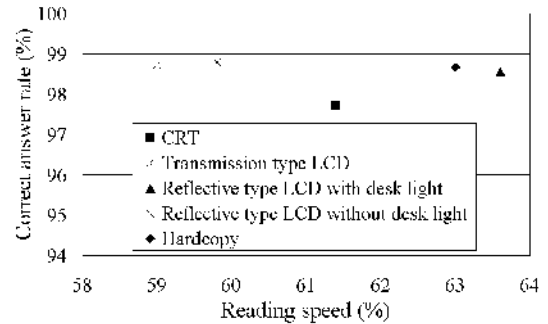


Figure 4. Reading speed and correct answer rate (Partly enlarged)

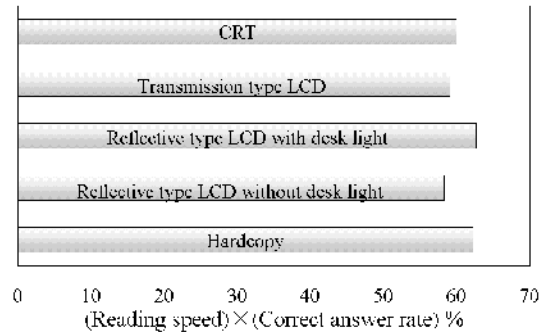


Figure 5. Effective reading speed

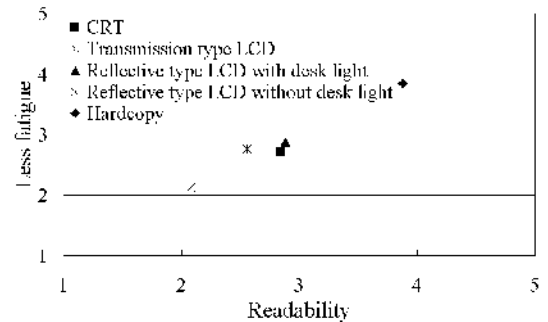


Figure 6. Subjective test results: fatigue and readability

We should remember that these results were collected for a simple task conducted over a short period of only 3 minutes. Another objective evaluation using a task with longer duration might show larger differences between the media; visibility and fatigue can greatly impact working efficiency in long time tasks. Remaining study items are to consider tasks that require more time to complete and tasks that involve more cognitive skills.

### Summary

Objective and subjective tests were carried out to clarify the difference, in terms of work performance, between hardcopy and three softcopy devices. The main results can be summarized as follows.

- 1) Large differences were not be seen in this study in an objective evaluation of effective reading speed between hardcopy and softcopy devices.
- 2) Large differences were found between the hardcopy and softcopy devices, in a subjective evaluation; hardcopy provided the greatest readability and least fatigue.
- 3) Subjective factors showed major differences in this evaluation for the simple and short-time task used in this study.

### References

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### Biography

Hirokazu Yoshikawa was born in 1976. He received his B.S. degree in 2000 from Tokai University. He is expected to receive his M.S. degree in Graduate School of Tokai University in 2002. He is now engaged in a study of Digital Paper technology at Tokai University.