

# Comparison of Thinking Efficiency between Softcopy and Hardcopy

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## Abstract

Information on VDT (Visual Display Terminal) is tend to be often printed as hardcopy only for the purpose of getting more comfortable reading conditions. Electric mail with large volume of texts, for instance, is frequently printed wastefully. The concept of Digital Paper, which has combined merits of softcopy and hardcopy, is recently proposed to solve these problems including ecological items. This study aims at comparison of operation efficiency between hardcopy work and softcopy work. Our goal is to clarify the reason why hardcopy work is generally comfortable for human, and to know human-interface requirements for the Digital Paper.

## Introduction

People often avoid reading documents on visual display terminals (VDTs) by using printed hardcopy, i.e. the printed versions. It is assumed that people tend to prefer reading hardcopy than softcopy, which is a generalized word for VDT usage. For example, long e-mails are often printed instead of reading them directly on the VDT screen. This tendency is clearly wasteful in terms of time and paper resource. However, the reasons for and the quantitative strength of this tendency have not been clarified yet.

This study aims at comparing the operation efficiency of hardcopy and softcopy usage. Our goal is to clarify comfortable work conditions for humans and also to clarify the goals of "Digital Paper": a novel medium that offers the merits of both softcopy and hardcopy.

## Experimental

### Contents of Experiments

Reading tasks with simple questions were given to each subject. Time taken and correct answer rates were measured. Two working states were tested: vertical state, which is common for softcopy, and horizontal state, which is common for hardcopy. Each subject was permitted to move around to find the position offering maximum viewing comfort. A liquid crystal display with back lighting was used as softcopy device. Questionnaires on the ease of comprehension and the degree of fatigue were given to the

subjects after finishing all trials. Essential conditions of our experiments are listed in Table 1.

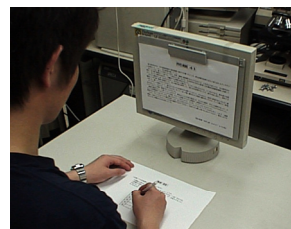
**Table 1. Experimental Conditions**

VDT	Liquid Crystal Display Resolution: 1024 768 Screen size: 13.8inch
Working Desk [Vertical State]	80(W) 70(D) 72(H) cm Surface color: White
Working Desk [Horizontal State]	91(W) 45(D) 71(H) cm Surface color: White
Clip Board	32(W) 23.5(D) cm Color: Gray
Environment	Illumination: 600lx (Fluorescent light) Room temperature: 25C
Testees	5 male students Average age: 22.6

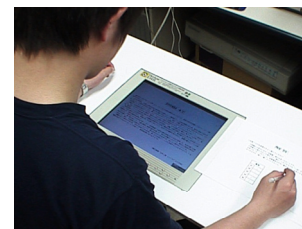
## Working Conditions

### (a) Vertical State

Softcopy materials were presented on a vertically set LCD connected to a personal computer. The hardcopy materials were given on A4 size papers on a clipboard attached to the LCD (Fig.1 (a)).



(a) Vertical State  
[Hardcopy]



(b) Horizontal State  
[Softcopy]

Figure 1. Working Scenes

### (b) Horizontal State

Softcopy materials were presented on a horizontal LCD built into a special desk (Fig.1 (b)). Hardcopy materials were presented on A4 papers on a clipboard attached to the front of the LCD.

### Tasks and Job Sequence

The reading materials, columns containing approximately 749 Japanese characters, were extracted from the daily short Asahi newspaper column "Tensei-jingo." The same word processing program was used to form the reading materials: the same 13.5 point font was used in all cases. The tasks given to the subjects were to count the number of parts written in passive voice and to write the number on answer. All the tests were carried out from pm 15: 00 to pm 21: 00 except the training round, which was carried out from pm 13: 00 to pm 19: 00. Subjects were ordered to write answers on answer sheets on the desk. Subjects were told to read each column only one time and to finish their jobs as quickly as possible. The time taken to complete a trial ranged from 5 minutes (minimum) to 11 minutes (maximum). The first and second days were used as the practice round, and the results were ignored.

**Table 2. Order of Experiments**

	Round 1	Round 2	Round 3
Horizontal state	1st day	3rd day	5th day
Hardcopy	1	6	9
Softcopy	2	5	10
Vertical state	2nd day	4th day	6th day
Hardcopy	3	8	11
Softcopy	4	7	12

The correct answer rate for a trial was obtained by summing the absolute differences for the 5 columns between the correct numbers of passive voice parts and the numbers indicated by the subject for those columns, expressing the total as a percentage of the total number of actual passive voice parts, and then subtracting the resulting percentage from 100.

### Experimental Result

Figure 2 shows average reading speeds for the 5 subjects tested for each of the 4 states. Correct answer rates are shown in Fig. 3. Reading speeds were calculated for each subject by counting average characters read per second. Figure 2 shows that the hardcopy work offered higher reading speed in vertical states, while softcopy offered higher reading speed in horizontal state. Figure 3 shows that hardcopy offered higher correct answer rate both in horizontal state and vertical state.

Figure 4 summarizes the correct answer rates versus reading speed for the 4 combinations of media and states. Figure 5 shows comparison of effective reading speeds, which was defined as a product of reading speed and correct answer rate, between 4 working conditions. Figure 5 indicates important results that effective reading speeds

were always higher in hardcopy both in vertical state and horizontal state, and that effective reading speeds were always higher in vertical states both in hardcopy and softcopy work.

Subjective evaluation results, which were obtained from the questionnaires filled out by all subjects after the 3 rounds of tests, are plotted in Fig. 6 and Fig. 7. The questionnaires asked the subject to rank the combinations in terms of ease of comprehension (position 1: easiest to comprehend to position 4: most difficult to comprehend) and the level of fatigue (position 1: most fatiguing to position 4: least fatiguing). Four, three, two, and one points were assigned to the 1st, 2nd, 3rd, and 4th positions, respectively. Fig. 6 and Fig. 7 indicate that hardcopy in horizontal state provided the greatest ease of comprehension and the least fatigue. The horizontal state was superior (according to the subjective scores) to the vertical state for both media.

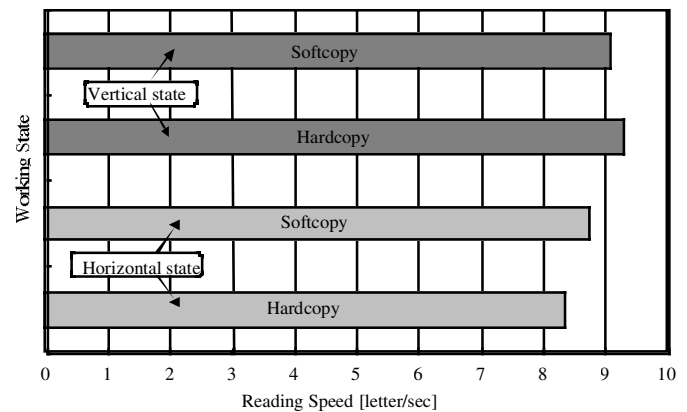


Figure 2. Average Reading Speed

### Discussion

Objective test results indicates superiority of hardcopy work as advantage of effective reading speed. Objective test results also indicates superiority of vertical state as same.

The superiority of hardcopy is almost supported by the results of subjective tests. However, when we compare vertical state and horizontal state, there seems to be a conflict between objective test results and subjective test results. A possible explanation for this result is that the stressful vertical state increased mental tension and consequently increased working efficiency for simple tasks.

More complicated tasks than that examined here are expected another tendency of results that shows superior working efficiency in horizontal state, which is less stressful. More complicated or creative tasks should be prepared to confirm this assumption.

The exceptionally low correct answer rate exhibited by the softcopy (horizontal state) is considered to be due to the poor display characteristics of the LCD due to its viewing angle restriction.

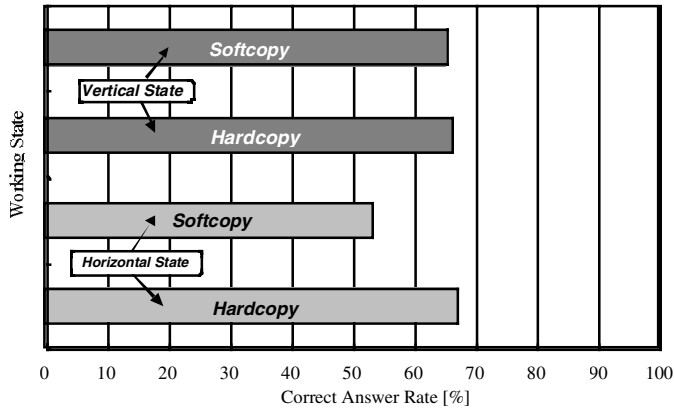


Figure 3. Average Correct Answer Rate

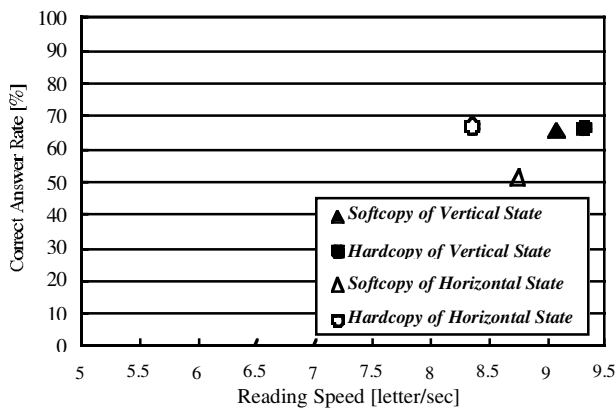


Figure 4. Reading Speed and Correct Answer Rate

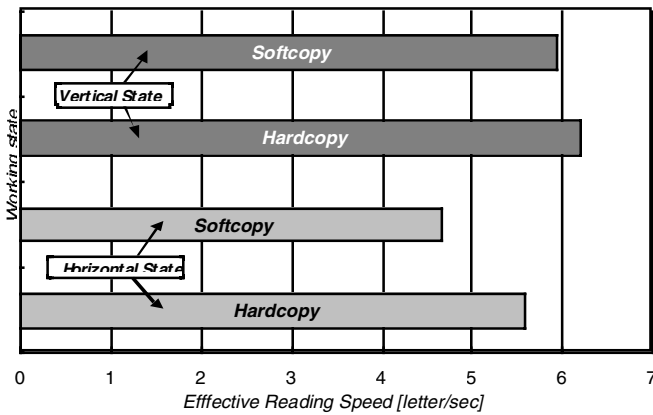


Figure 5. Effective Reading Speed

### Summary

Objective tests and subjective tests were carried out to clarify the difference between hardcopy and softcopy media. The main results can be summarized as follows.

- (1) The objective test results showed superiority, as advantages of effective reading speed, of hardcopy works and vertical states.
- (2) The subjective test results showed that hardcopy work in horizontal state was preeminently comfortable and that the horizontal state was generally more comfortable than the vertical state for both media.
- (3) The unexpected superiority, in objective tests, of vertical state which showed low scores at subjective tests, can be explained by a hypothesis that the stressful condition increased mental tension and increased working efficiency for simple tasks.

More complex tasks and more subjects should be prepared to obtain reliable conclusion for this theme. We expect this study to trigger the development of this new field of research.

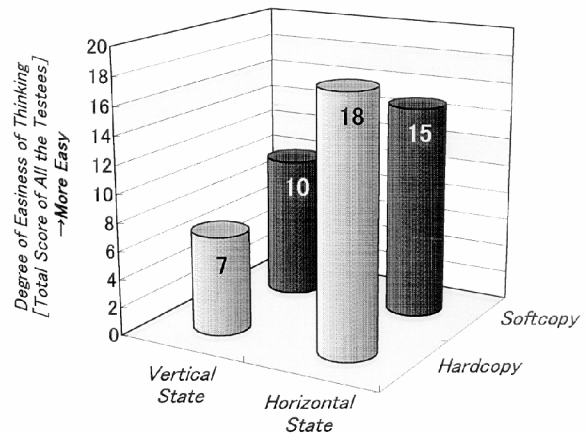


Fig.6 Subjective Test Results on Easiness of Thinking

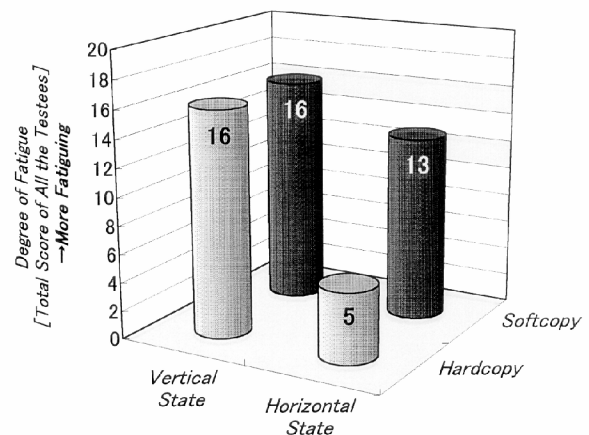


Fig.7 Subjective Test Results on Degree of Fatigue

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## Biography

Naoto Uchiyama was born in 1977. He entered Department of Electro-Photo Optics in Tokai University in 1996. He is now engaged in the study of Digital Paper.  
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