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NOTE

Eye fatigue-reduction effect of wood rim cover on liquid crystal display

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Abstract The purpose of this study is to confirm objectively by an instrumental measurement if there is less eye fatigue in VDT work when using a wood rim covered display than when using a plastic housing display. The subjects were 26 graduate and undergraduate university students. Each subject did the same 60-min VDT activity with both a plastic housing and wood-covered display. Before and after VDT activity, each subject's near-point accommodation distance was measured by a near-point ruler. As a result, it was confirmed that variation rate of the near-point accommodation distance by the VDT work with the wood-covered display was smaller than with the plastic housing display. From sensory tests, progression of subjective symptoms such as eye pain and headache was less with the wood-covered display than with the plastic housing display.

Keywords VDT work · Computer vision syndrome · Eye fatigue · Wood · Near-point accommodation

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Introduction

In our modern life, we cannot avoid doing work with visual display terminals (VDT), and there are many reports [1–3] on eye or body fatigue from VDT use, which is called computer vision syndrome (CVS). A study [4] on VDT work fatigue mentioned that most subjects complained of eye fatigue. This problem of eye fatigue should be of great concern. There are reports that eye fatigue decreases by decreasing the reflective glare [5] and appropriately lowering the brightness of the monitor [6, 7].

On the other hand, there is a report [8] that describes how wood surfaces reduce the eye fatigue. It says that the anatomical level relief structure of wood surfaces induces light to scatter and diminishes surface glare. We considered whether eye fatigue on VDT work might decrease by utilizing this characteristic of wood.

Therefore, in our previous reports [9, 10], we verified eye fatigue subjective symptom changes between a plastic housing display ("plastic display" from now on) and a display with an attached wood sliced veneer on the front rim surrounding the display screen ("wood-covered display" from now on). In these reports, we required test subjects to do 10 min of Internet reading of the same content on these two type displays. In the sensory test, a significant number of subjects felt less eye fatigue with the wood-covered display than with the plastic display [9, 10].

This study is intended to verify objectively whether there is an eye fatigue-reducing effect in VDT work by using a wood-covered display. For this purpose, we employed a near-point ruler and measured subjects' near-point accommodation ("NPA" from now on) distance as the index of degree of eye fatigue. It is generally said that NPA distance, the least distance that an object is seen

Fig. 1 Two kinds of crystal liquid display **a** and **c** = **a** + **b**

Table 1 Test procedure

	Stage	Required time (min)	Contents
Practice	1	10	NPA measurement training
First test	2	5	Subjective symptoms investigation
	3	5	NPA measurement
	4	60	VDT work with plastic/ wood-covered display
	5	5	NPA measurement
	6	5	Subjective symptoms investigation
Pause	7	15	Eye rest
Second test	8	5	Subjective symptoms investigation
	9	5	NPA measurement
	10	60	VDT work with wood-covered/ plastic display
	11	5	NPA measurement
	12	5	Subjective symptoms investigation
Ending	13	3	Concluding impression inquiry
Total time		188	

Each NPA measurement was carried out five times. The second shortest NPA value was employed as the result of the stage

clearly, gradually elongates with the decline of focus adjustment ability of the eye due to fatigue [6].

Methods

Preparation of wood-covered display

A 17-in. liquid crystal display with plastic housing (I O DATA LCD-A176GW, housing color: white, analog type) was prepared, as shown in Fig. 1a. The surface finish of the plastic housing was pearskin. A boundary attachment to the display screen was made of plywood, thickness 2.5 mm. Flat grain sliced veneers of Japanese ash (*Fraxinus mandshurica* var. *japonica*), thickness 0.33 mm with no surface treatment, were bonded so that the grain was oriented horizontally (Fig. 1b). Widths of the boundary attachment and sliced veneers were equal to the front rim width of the display screen. Japanese ash was selected for its uniform and light color, and for its light-scattering characteristics with large vessels. The boundary attachment was pasted on the display rim with double-stick tape (Fig. 1c).

Test procedure

Table 1 shows the test procedure. By this procedure, half of the subjects took a VDT work test with the plastic display in the first test and then with the wood-covered display in the second test. The rest of the subjects took the tests in reverse order. The 60-min work sessions include the same content in the first and second tests. The work consists of the same contents for each subject as follows: "document reading", "watching binary and hexadecimal notations movement", "searching for mistakes", "watching moving scenery from the window of a train/car", etc. These contents were selected to represent various VDT activities.

The subjects were 26 graduate and undergraduate students (average age: 24.2 years old (standard deviation: 7.2 years old), men: 22, women: 4) of the Okayama University. Among them, 14 wore eyeglasses, 4 used contact lenses, and 8 used no sight correction. Their average eyesight with both eyes was 1.01 (standard deviation: 0.21). Consent was obtained as a written form from each subject by informing them of the research aim and the possibility that obtained data would be used as anonymous quotes in publications.

The test was carried out during the daytime, fixing the environment as follows: a display with its own originally equipped brightness adjustment function was put on a desk covered by white cloth. White plasterboards were set behind the display. The window blinds were pulled down and fluorescent lights in the ceiling were turned on, confirming no reflection glare was on the display screen and

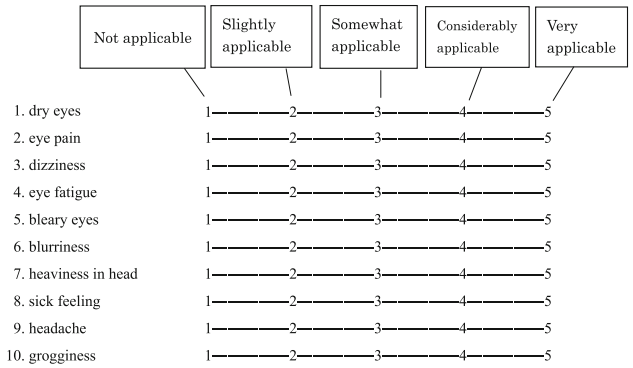

Fig. 2 Inspection paper for the subjective symptoms test used in stages 2, 6, 8 and 12 of Table 1

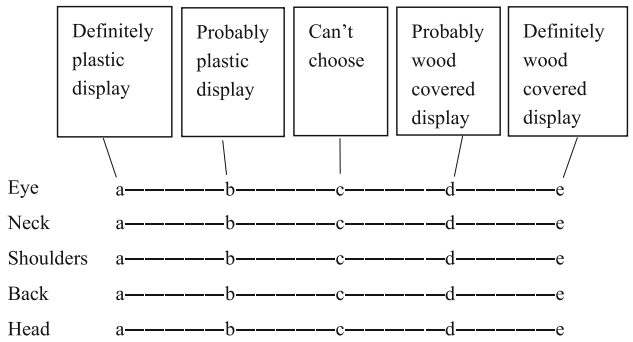

Fig. 3 Inspection paper to ask which display seems to induce less fatigue on the indicated body part (used in the 13th stage of Table 1)

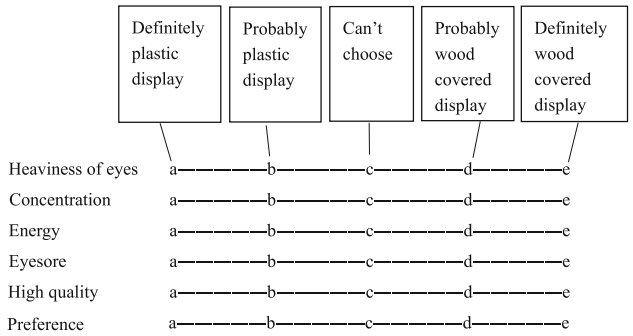

Fig. 4 Inspection paper to ask which display seems to fit best to each term (used in the 13th stage of Table 1)

rim. Illumination on the desktop was about 400 lx. Vertical illumination on the display screen was about 300 lx. Both illumination levels were adapted to guidelines for labor hygiene management on VDT work [11] in Japan.

The distance between the display screen and the subjects' eyes was 40–65 cm according to their physiques and preferences. Subjects' eyes were a little higher than the upper display rim. We let subjects regulate the angle of the display screen, so that it was easy to read and watch.

The temperature in the test room was regulated to be comfortable as needed by using an air-conditioner.

NPA measurement

An objective test of eye fatigue was performed by measuring the NPA with a near-point ruler (WOC Co. "D' ACOMO") on both eyes. A report [12] mentions that the NPA showed high objectivity and reproducibility in the obtained data.

NPA measurements were carried out at stage 3, 5, 9 and 11, as seen in Table 1.

The NPA variation rate was defined by the following expression:

$$\text{NPA variation rate} = \frac{\text{NPA after VDT work (cm)}}{\text{NPA before VDT work (cm)}} \times 100(\%) \quad (1)$$

It is understood that large NPA variation rate means increased eye fatigue.

Sensory test

Adding to objective measurement of eye fatigue, sensory tests were carried out.

In this study, ten items concerning eye and head symptoms were extracted from "The subjective symptoms investigation" [13] question paper by the Japan Society for Occupational Health Industry as shown in Fig. 2. This test was carried out at stage 2, 6, 8 and 12 in Table 1.

From each answer item, changes in subjective symptoms level were obtained by the following expression:

$$\begin{aligned}&\text{Changesin subjective symptoms level}\\&= \text{subjective symptoms level after VDTwork}\\&\quad - \text{subjective symptoms level before VDT work}\end{aligned} \quad (2)$$

Concluding impression inquiry

At the final stage of the test procedure, subjects were asked which display seemed to induce less fatigue on neck, shoulders, back and head, as in previous reports [9, 10] (Fig. 3). They were also asked which display seemed to fit better to the following terms: subject feels more heaviness of eyes (heaviness of eyes), subject feels it easier to concentrate (concentration), subject feels more energetic (energy), display is unpleasant to look at (eyesore), display seems more high quality (high quality) and subject prefers the display (preference) (Fig. 4).

These questions had five choices made up of a–e as shown in Figs. 3 and 4. Each subject was instructed to choose only one from five.

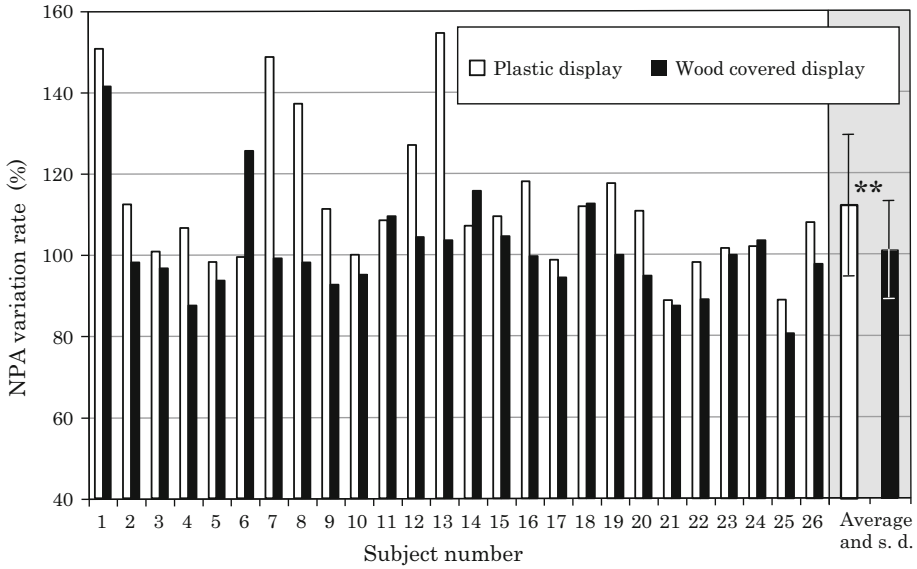

Fig. 5 NPA variation rate of individual subjects obtained by expression (1). Odd numbered subjects did VDT work with the plastic display as the first test in Table 1, and even numbered subjects worked with the wood-covered display as the first test. Average difference was significant at 1% level (**)

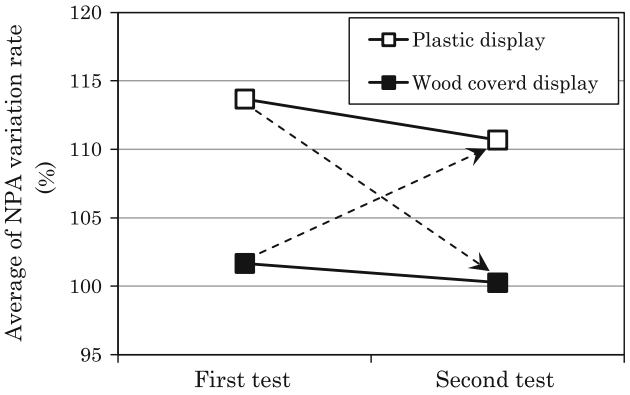

Fig. 6 Differences in NPA variation rate between the testing order. *Dashed arrows* indicate the testing order of individuals

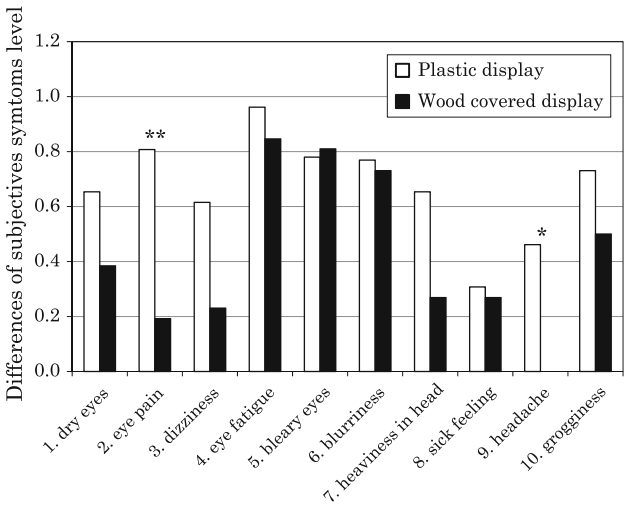

Fig. 7 Average of subjective symptom level changes obtained by expression (2). Average differences were significant at the 5% (*) and 1% levels (**)

Results and discussion

NPA measurement

Figure 5 shows each subject's NPA variation rate obtained by expression (1). In Fig. 5, odd numbered subjects did VDT work with the plastic display as the first test in Table 1, and even numbered subjects did VDT work with the wood-covered display.

There are great differences between individuals in NPA variation rate. The average of NPA variation rate with the plastic display is 112%, but with the wood-covered display the variation is 101%, meaning that in the latter case eye fatigue scarcely increased. By the paired t test, there was a significant difference of 1% level between the averages, and that of the wood-covered display was smaller than that of the plastic display. Various characteristics of Japanese ash seemed to decrease eye fatigue.

In Fig. 6, the effect of testing order of VDT work on NPA variation rate is shown. It was understood that NPA variation rate with the wood-covered display was smaller than that with the plastic display in both the first and second test. In addition, it was seen that NPA variation rate of the first tests was larger than that of the second tests, with both displays. We would think that this tendency shows the length of pause between tests (stage 7 in Table 1) was insufficient to recover the eye function, or the subjects were accustomed to the VDT work at the second test.

From these NPA measurement results, it was verified objectively that the wood cover on the display rim had the effect of reducing eye fatigue in VDT work.

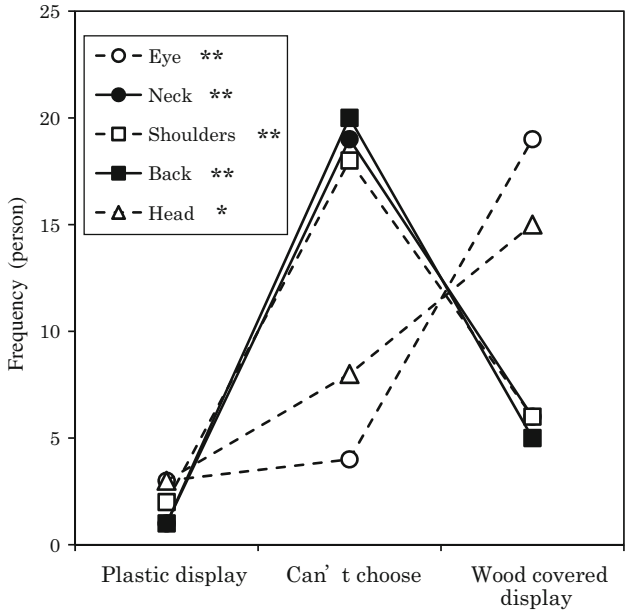

Fig. 8 Relationship between display and apparent fatigue on each body part. Differences in the three groups' ratios analyzed using the Chi-square distribution [14] were significant at the 5% (*) and 1% levels (**)

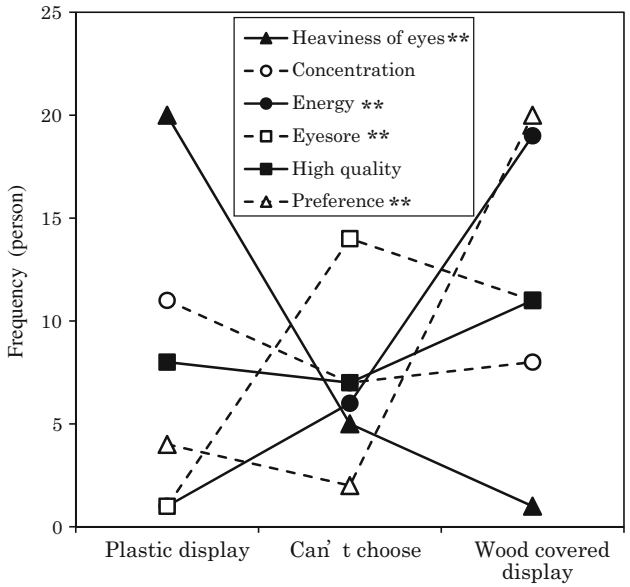

Fig. 9 Relationship between display and terms which seemed to fit better. Differences in the three groups' ratios analyzed using the Chi-square distribution [14] were significant at the 1% level (**)

Changes in subjective symptom level

Figure 7 shows the changes in subjective symptoms levels obtained by expression (2). In all inquiry items except one, this value was smaller with the wood-covered display than with the plastic display. From the paired *t* test, there were significant differences of 1 and 5% between the plastic display and the wood-covered display in "2. Eye pain" and "9. Headache", respectively.

From the sensory tests on the subjective symptom level, it was understood that the effect of the wood cover mainly appeared in decreasing eye pain and headache rather than eye fatigue.

Impression on display's difference

Figure 8 shows the results of the sensory test shown in Fig. 3. Here, the counts on "*a* definitely plastic display" and "*b* probably plastic display" were summed up to "plastic display", and "*d* probably wood-covered display" and "*e* definitely wood-covered display" were summed up to "wood-covered display". Most of the subjects answered they "can't choose" which display gave less fatigue with neck, shoulders and back. But with eye and head, many subjects answered that they felt less fatigue from the "wood-covered display" than from the "plastic display".

Figure 9 shows the results of the sensory test shown in Fig. 4. The data were treated the same as in Fig. 8. Many subjects felt "heaviness of eyes" with the "plastic display", and they thought that the terms "energy" and "preference" fit the "wood-covered display".

Figures 8 and 9 also show the results analyzed by the difference significance tests of three ratios using the Chi-square distribution [14]. The above-mentioned results were verified to be almost significant.

In this study, it was proved that, not only on the subjective symptom level but also on the physiological level, wood had a fatigue-reducing effect during VDT work, when it was used as the rim cover on a plastic display. We hope our results will be appreciated by the VDT workers in offices, educational institutions and homes.

Conclusions

To confirm objectively the eye fatigue-reducing effect of wood covering on a normal plastic display, NPA measurements were done during controlled VDT work. A few sensory tests were also employed. The following results were obtained.

1. NPA variation rate after VDT work was smaller using a wood-covered display than using a plastic display. Therefore, it was confirmed objectively that wood covering has an eye fatigue-reducing effect.
2. From the sensory test, fewer subjective symptoms were reported with the wood-covered display than with the plastic display.

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