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NOTE

Reducing eye fatigue through the use of wood

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Abstract To clarify if eye fatigue is lessened when looking at wood, we carried out objective examinations using a near-point ruler and also performed sensory evaluations. Visual contact target materials were a white plastic panel, a black plastic panel or a wood panel which had Japanese ash flat grain surface. Each size of the materials was 140 × 280 mm. Test subjects were 30 undergraduate and graduate students. Each subject's visual distance to a panel was 40–50 cm. The results showed that subjects suffered from more eye fatigue when looking at white and black plastic panels compared to looking at the wood panel in objective examinations. In sensory evaluations, almost all subjective symptom items for eyes and head progressed when subjects looked at white plastic panel or black plastic panel. However, almost no progression of subjective symptoms was noted when subjects looked at the wood panel. In both objective examinations and sensory evaluations, eye fatigue was most highly associated with the black plastic panel, followed by the white plastic panel and, finally, the wood panel.

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Introduction

The literature has shown that wooden surfaces reflect only a tiny fraction of ultra-violet rays; with its microscopic unevenness, the surface of wood disperses light and reduces glare, lessening fatigue on the eyes [1]. However, this reduction in eye fatigue when looking at wood has not been objectively clarified.

In our previous studies [2, 3] involving visual display terminals (VDT) work, which produces a high degree of eye fatigue [4–6], we considered wood affixed around a liquid crystal display (LCD) screen for decreasing eye fatigue. For visual appeal, flat grain surface of a widespread broadleaf tree species, Japanese ash (*Fraxinus mandshurica* var. *japonica*), was chosen. We attached the wood to a rim around an LCD screen. Referring to literatures [7, 8] about relationships between eye fatigue and the near-point distance ("NPD", hereafter) with a near-point ruler commonly used in the industrial health field, we measured NPD to objectively clarify that there was less eye fatigue than when a plain LCD screen was utilized. We examined how display screens used for VDT tasks and the wood surrounding the screen affected test subjects. The results suggested that when the subjects only looked at the wood surface, they experienced less eye fatigue.

In an effort to objectively clarify whether only looking at a wood surface truly alleviates eye fatigue, as reported by previous studies [2, 3], the present study used Japanese ash flat grain surface and involved measuring NPD with a near-point ruler.

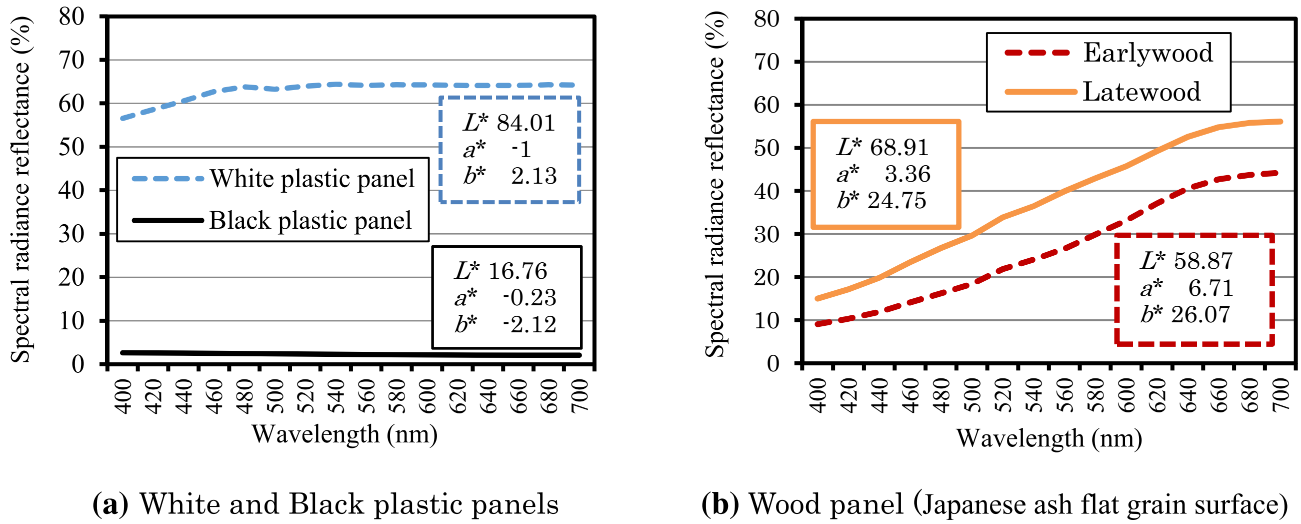

Fig. 1 Spectral radiance reflectance and color value of visual contact target materials

If it can be shown that eye fatigue is decreased by looking at wood surfaces, it is thought that future use of wood will spread.

Methods

Visual contact target materials

In addition to wood (Japanese ash flat grain surface, specifically), white plastic and black plastic were also used as visual contact target materials, with eye fatigue examined and compared after subjects looked at each target material. Each of these materials was rendered onto 140 × 280 mm panels and positioned horizontally. For the white and black plastic panels, the materials selected were almost identical to those of the LCD screen chassis used in previous studies [2, 3]. We created a wood panel by pasting 0.3 mm-thick fancy veneer of Japanese ash flat grain surface on one side of 2.5 mm-thick plywood.

Figure 1 shows the spectral reflectivity and color for each visual contact target material. Figure 1a demonstrates that the white plastic panels are quite reflective across all wavelength ranges, while conversely the black plastic panels have low reflectivity across all wavelength ranges. Figure 1b demonstrates that with the wood surface, both the earlywood and latewood parts have features typical of wood, with shorter wavelengths producing low reflectance and longer wavelengths producing higher reflectance. The fact that the earlywood part has lower reflectance is thought to be due to the existence of vessels in the earlywood part of Japanese ash.

Figure 2 shows the spectral reflectivity and color of the plastic panels used for white and black housings displays

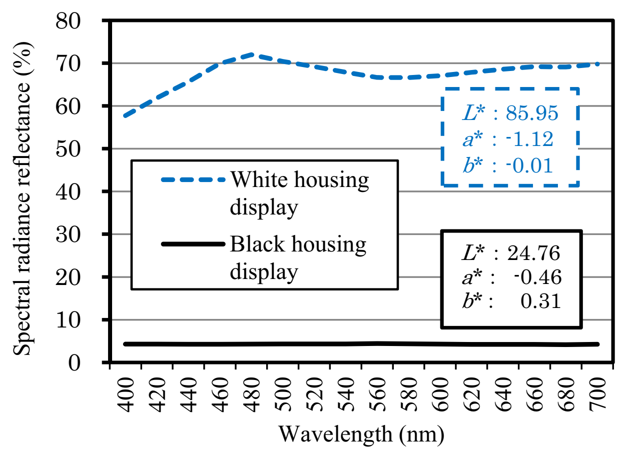

Fig. 2 Spectral radiance reflectance and color value of plastic display housing used in previous studies [2, 3]

used in previous studies [2, 3]. The spectral reflectivity of the white plastic and black plastic panels used in the present study (Fig. 1a) is similar to that (Fig. 2) of the white and black plastic panel of the LCD housing used in the previous studies [2, 3].

Testing methods

As shown in Fig. 3, the visual contact target material was positioned on a monitor stand placed on a desk. Subjects were asked to sit on chairs positioned such that they could see the display screen for VDT work and then to look at the target materials. The visual contact target materials were positioned such that they were slightly lower than eye level and at a visual distance of 40–50 cm from the subjects.

Table 1 indicates the examination procedures. In carrying out the examination for each test subject and each

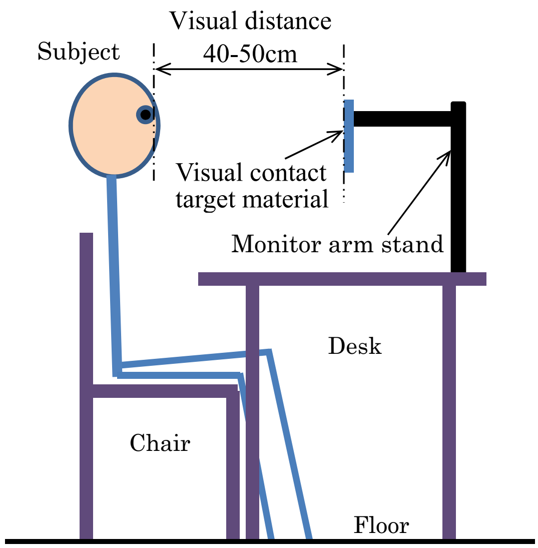

Fig. 3 The side view of subject gazing at the target material

visual contact target material, we performed three examinations. The first examination of the test material lasted 30 min. To allow subjects to rest their eyes, 2 h of rest was provided between each round of testing; sometimes, the next examination was performed on another day. Before each gaze at visual contact target material, NPD was measured and subjective examination of the eyes and head was also carried out in the form of a sensory test. Moreover, immediately after completing the third vision examination, we asked subjects to rank each target material based on eye fatigue and headaches.

Subjects included 30 undergraduate and graduate students (average age: 22.2 ± 3.0 years; 27 male and 3 female students), from O university, a public school. Twelve of the subjects wore neither glasses nor contact lenses, while 8 wore glasses and 10 used contact lenses. Eyesight was 1.07 ± 0.32 for the subjects. As outlined in Table 1, the objectives of the study were explained to each test subject and their consent was obtained before test.

The test was carried out during the daytime, fixing the environment as follows. Ceiling fluorescent lights were switched on. And by adjusting window shades, the brightness of the visual contact target material was kept 320–380 lx. We found that the reduced glare on the display accounted for less eye fatigue [9] with no reflection produced on the visual contact target material.

The wall behind the target material and the desktop with the monitor arm stand were covered with white canvas. And white canvas curtains were hung to the right and the left sides of the desk. Besides the visual target material, the only object within the field of vision of the subjects was the white canvas.

Objective testing through the use of a near-point ruler

The near-point ruler (WOC D'ACOMO) used in this examination was the same equipment used in previous studies [2, 3]. The measurement data produced by the D'ACOMO near-point ruler were reported to be highly objective and repeatable, thereby supporting their usefulness [10].

NPD was measured by the approaching method. And we calculated NPD variation rate using next Eq. (1).

$$\text{NPD variation rate} = \frac{\text{NPD after gaze at material (cm)}}{\text{NPD before gaze at material (cm)}} \times 100(\%) \tag{1}$$

According to Eq. (1), NPD variation rate >100% represents considerable eye fatigue. Conversely, a ratio <100% is thought to indicate elevated eye control function and lessened eye fatigue.

Table 1 Test procedure

Before test	Give test subjects an overview of examination and obtain their consent
	Practice measuring NPD using a near-point ruler
First test	(1) Subjective symptoms investigation of eyes and head before gaze
	(2) NPD measurement before gaze
	(3) Gaze at target material (30 min)
	(4) NPD measurement after gaze
	(5) Subjective symptoms investigation of eyes and head after gaze
Pause	2-h break or resume another day
Second test	(1)–(5) above examined for another target material
Pause	2-h break or resume another day
Third test	(1)–(5) above examined for the final target material
Rank three target materials for visual contact by degree of eye fatigue and headaches they produce	

The order of presentation of three target materials was randomized

NPD near-point distance

Sensory tests

Subjective sensory checks of eyes and head

Sensory evaluations carried out in previous studies [2, 3] of eye fatigue resulting from VDT work showed that displays that had a Japanese ash flat grain frame surrounding the screen helped to alleviate fatigue of the eye and the head. Therefore, similar to the previous studies [2, 3], the present study assessed ten items from the "subjective symptoms investigation" [11] by the Japan Industrial Safety and Health Association (2002), leading to the creation of a questionnaire (Fig. 4).

Looking at subjective symptoms investigation conducted before and after the gaze at the target material, changes in subjective symptoms level ("SSL", hereafter) were calculated for each item on the questionnaire using Eq. (2).

$$\text{Change of SSL} = \text{SSL after gaze at material} - \text{SSL before gaze at material} \quad (2)$$

A larger change of SSL reflects that the subjective symptoms demonstrate greater progression because of the gaze with target material. A negligible change in subjective symptom values can be interpreted to indicate that, for unknown reasons, the symptoms have been alleviated.

High rankings for eye and head fatigue

As shown in Table 1, after all three target materials were examined, rankings for both high eye and head fatigue were analyzed.

Results and discussion

Objective examination with a near-point ruler

Figure 5 demonstrates NPD variation rate for each test subject as calculated by Eq. (1). Unsurprisingly, Fig. 5 shows that there are individual NPD variation rates. The average for the visual contact target materials is indicated on the right side of the same figure. The ratio for both white and black plastic panels exceeded 100%, with values of 110.1 and 112.6%, respectively. Meanwhile, the wood panel had a ratio <100%, at 96.9%.

The symbols at the end of the bar on the right side of Fig. 5 indicate paired *t* test results for the difference between the average value of each visual contact target material and the hypothesized average degree of variability in the NPD of 100% when there is no change in eye fatigue. As results of having examined the difference of the mean, the following findings were obtained. For both types of plastic panel, a significant difference in the 1% standard was observed, which can be interpreted as indicating that eye fatigue increased because of the visual contact. The wood panel fell short of 100% and a significant difference in the 5% standard was observed. Consequently, it was suggested that the control functions of the eye improved, leading to less eye fatigue. It is objectively clear that there was a reduction in subject eye fatigue when the subjects looked at the wood panel.

Table 2 shows the paired *t* test results for the difference in average values between each visual contact target material in Fig. 5. A significant difference in the 5% standard was recognized between the white and black plastic panels. Significant differences in the 1% standard were observed between each of the white and black plastic panels and the wood panel.

Figure 5 and Table 2 show that eye fatigue was most highly associated with black plastic panel, followed by the white plastic panel and, finally, the wood panel.

Sensory evaluation

Eye and head subjective symptoms investigation

Figure 6 shows the average change of SSL for each subjective symptom related to the eyes and head. The symbols at the end of each bar in Fig. 6 indicate the significant differences by paired *t* test in average values between the mean of each item and an average SSL of 0 indicating no progression in subjective symptoms. And Table 3 shows *P* values of each subjective symptom item by the *t* test in Fig. 6.

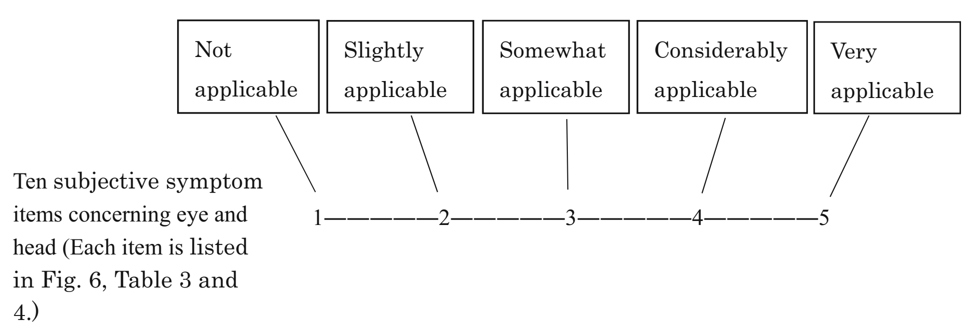

Fig. 4 Questionnaire for eye and head subjective symptoms test

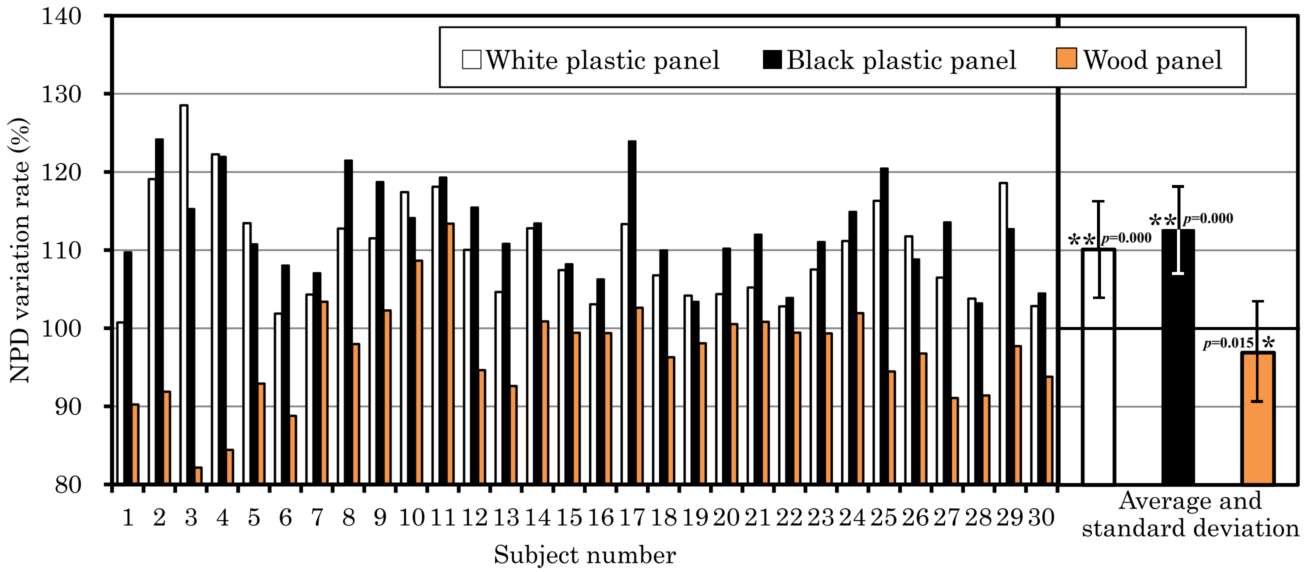

Fig. 5 NPD variation rate of individual subjects obtained by Eq. (1). *P* values are shown at the end of average bar by paired *t* test between each average of NPD variation rate of visual contact target material and average of NPD variation rate of 100%. And this paired *t* test results: $*p < 0.05$, $**p < 0.01$. Significant difference of 1% standard by paired *t* tests is recognized between average of wood panel and averages of both plastic panels, respectively. *NPD* near-point distance

Table 2 Paired *t* test results of differences between visual contact target materials concerning average of NPD variation rate in Fig. 5

White plastic panel – Black plastic panel	*	$p = 0.010$
White plastic panel – Wood panel	**	$p = 0.000$
Black plastic panel – Wood panel	**	$p = 0.000$

NPD near-point distance

$*\ p < 0.05$, $**\ p < 0.01$

Significant differences were noted in seven items for the white plastic panel (“1. dry eyes” through “7. heaviness in head”) and for all items for the black plastic panel. Meanwhile, no significant difference was noted for almost all items for the wood surface. Hence, we can assume that there is almost no progression in subjective symptoms for visual contact involving the wood panel.

Table 4 shows significantly different examination results by paired *t* test among all visual contact target materials in Fig. 6. There were several items for which a significant difference was obtained when comparing the white and black plastic panel and the wood panel. In particular, there were a large number of entries with significant differences when comparing the black plastic panel and the wood panel.

To calculate the changes in SSL compiled for the eyes and head, for each test subject, we computed the total number of entries related to the eyes (“1. dry eyes” through “6. blurriness”) and the total number of items related to the head (“7. heaviness in head” through “10. grogginess”). Table 5 contains the average values for all subjects. The same table also shows the calculations for the significant differences in the 1 and 5% standards by paired *t* test between the visual contact target materials for both eye-related and head-related entries. Consequently, we saw that for both the eyes and the head, a significant progression of subjective symptoms was most evident with the black plastic panel, followed by the white plastic panel and, finally, the wood panel (Table 5).

High rankings for eye and head fatigue

Table 6 shows the averages for the high rankings for both the eye and head fatigue that were recorded at the conclusion of the examination processes in Table 1. Table 6 also shows the paired *t* test results for differences in the average values related to fatigue rankings.

In Table 6, a significant difference in the 1% standard was found between each visual contact target material for both eye and head fatigue, with these differences most pronounced for the black plastic panel, followed by the white plastic panel, and finally, the wood panel. Of particular note is that subjects unanimously selected the wood surface as the material producing the least eye and head fatigue.

Consistency of objective examination and sensory evaluation results related to eye fatigue

With objective examinations of eye fatigue carried out using a near-point ruler, the greatest amount of fatigue was

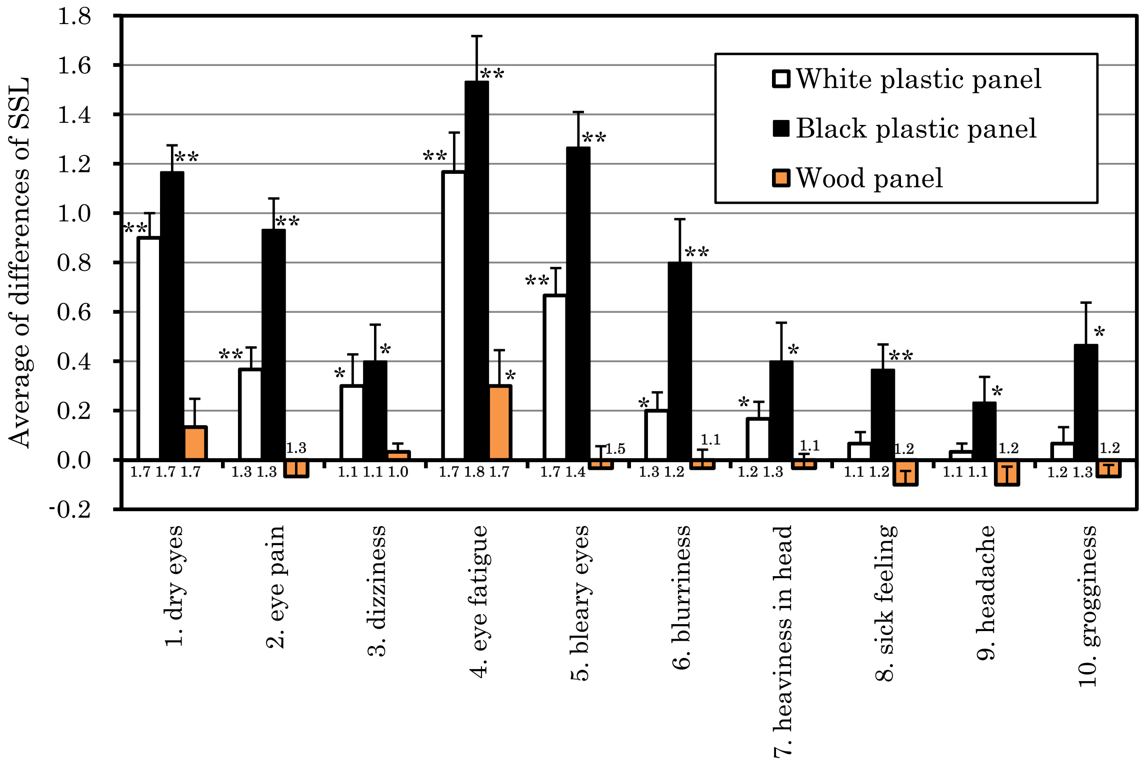

Fig. 6 Averages of SSL changes obtained by Eq. (2). Averages of SSL before gaze in Table 1 are shown at the neighborhood of 0.0 SSL of each bar. Standard errors only for plus were shown at the end of each bar. Paired *t* test results of differences between average SSL changes by item and average SSL of 0.0: *$p < 0.05$, **$p < 0.01$. *SSL* subjective symptoms level

Table 3 *P* values by paired *t* test of each subjective symptom item shown in Fig. 6

Subjective symptoms items	White plastic panel	Black plastic panel	Wood panel
1. dry eyes	0.000	0.000	0.255
2. eye pain	0.000	0.000	0.326
3. dizziness	0.026	0.012	0.326
4. eye fatigue	0.000	0.000	0.048
5. bleary eyes	0.000	0.000	0.712
6. blurriness	0.012	0.000	0.662
7. heaviness in head	0.023	0.016	0.573
8. sick feeling	0.161	0.001	0.083
9. headache	0.326	0.032	0.184
10. grogginess	0.326	0.011	0.161

evident with the black plastic panel, followed by the white plastic panel and, finally, by the wood panel. This order is similar to both that of the subjective symptom testing of the eyes and examinations resulting in rankings indicating a high degree of eye fatigue.

Conclusions

To clarify if eye fatigue is lessened when looking at wood surface, we carried out objective observations using a near-point ruler and also performed sensory evaluations using questionnaires. From comparing the three visual contact target materials (a white plastic panel, a black plastic panel, and a wood panel which had fancy veneer of Japanese ash flat grain surface), the following results were obtained.

1. Objective examinations showed that subjects suffered from eye fatigue when looking at white and black plastic panels but when subjects looked at the wood panel, they seemed to experience improved eye control function and less eye fatigue.

Table 4 Paired *t* test results of differences between visual contact target materials concerning average of SSL changes in Fig. 6

Subjective symptoms items	White plastic panel − black plastic panel		White plastic panel − wood panel		Black plastic panel − wood panel	
	Mean differences (s. d.)	*P* values	Mean differences (s. d.)	*P* values	Mean differences (s. d.)	*P* values
1. dry eyes	−0.27 (0.69)	* 0.043	0.77 (0.73)	** 0.000	1.03 (0.72)	** 0.000
2. eye pain	−0.57 (0.73)	** 0.000	0.43 (0.63)	** 0.001	1.00 (0.83)	** 0.000
3. dizziness	−0.10 (0.80)	n. s. 0.501	0.27 (0.64)	* 0.030	0.37 (0.85)	* 0.025
4. eye fatigue	−0.37 (1.25)	n. s. 0.118	0.87 (0.82)	** 0.000	1.23 (1.22)	** 0.000
5. bleary eyes	−0.60 (0.93)	** 0.001	0.70 (0.79)	** 0.000	1.30 (0.99)	** 0.000
6. blurriness	−0.60 (1.07)	** 0.005	0.23 (0.43)	** 0.006	0.83 (1.14)	** 0.000
7. heaviness in head	−0.23 (0.94)	n. s. 0.182	0.20 (0.48)	* 0.031	0.43 (0.90)	* 0.013
8. sick feeling	−0.30 (0.54)	** 0.005	0.17 (0.46)	n. s. 0.057	0.47 (0.68)	** 0.001
9. headache	−0.20 (0.55)	n. s. 0.056	0.13 (0.43)	n. s. 0.103	0.33 (0.66)	* 0.010
10. grogginess	−0.40 (0.97)	* 0.031	0.13 (0.51)	n. s. 0.161	0.53 (0.97)	** 0.005

SSL subjective symptoms level, *s. d.* standard deviation, *n. s.* not significant

* $p < 0.05$, ** $p < 0.01$

Table 5 Average of sums of items concerning eye and head in Fig. 6

	Sum of items concerning eye 1+2+・・・+6	Sum of items concerning head 7+8+9+10
White plastic panel (s. d.)	3.60 (1.84)	0.33 (0.79)
Black plastic panel (s. d.)	6.10 (2.80)	1.47 (2.43)
Wood panel (s. d.)	0.33 (1.68)	-0.30 (0.78)
White – Black	** p=0.000	** p=0.019
Black – Wood	** p=0.000	** p=0.001
White – Wood	** p=0.000	** p=0.004

s. d. standard deviation
Paired t-test results of differences between visual contact target materials
** p < 0.01

Paired *t* test results of differences between visual contact target materials

s. d. standard deviation

* $p < 0.05$, ** $p < 0.01$

Table 6 Average of order of each visual contact target material concerning with much eye fatigue and head fatigue

	Average of eye fatigue (s. d.)	Average of head fatigue (s. d.)
White plastic panel	1.8 (0.4)	1.8 (0.4)
Black plastic panel	1.2 (0.4)	1.2 (0.4)
Wood panel	3.0 (0.0)	3.0 (0.0)
White – Black	** p=0.000	** p=0.000
Black – Wood	** p=0.000	** p=0.000
White – Wood	** p=0.000	** p=0.000

s. d. standard deviation
Paired t-test results of differences between visual contact target materials
** p < 0.01

Paired *t* test results of differences between visual contact target materials

s. d. standard deviation

**$p < 0.01$

2. We performed subjective symptom evaluation of the eyes and head in the form of a sensory test, observing the progression of subjective symptoms for almost all items when subjects looked at white and black plastic panels. However, almost no progression of subjective symptoms was noted when subjects looked at the wood panel.
3. At the conclusion of the examination, subjects unanimously selected the wood panel as the visual contact target material producing the least eye and head fatigue.
4. In objective examinations and two types of sensory evaluation, eye fatigue was most highly associated

with the black plastic panel, followed by the white plastic panel and, finally, the wood panel.

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