Effect of an Eyesight Recovering Stereoscopic Movie System on Visual Acuity and Asthenopia

Akihiro Sugiura[1], Tetsuya Yamamoto[1], Hiroki Takada[1], and Masaru Miyao[2]

[1] Department of Radiology, Gifu University of Medical Science
795, 1, Ichihiraga Nagamine, Seki, Gifu, Japan
{asugiura,yamamoto,takada}@u-gifu-ms.ac.jp
[2] Central Information Center, Nagoya University
Huro-tyou, Chikusa-ku, Nagoya, Aichi, Japan
miyao@itc.nagoya-u.ac.jp

Abstract. Relaxing the contracted muscles involved in focus-adjustment around the eyeball, such as the ciliary body and extraocular muscles, is expected to improve pseudomyopia. This hypothesis has led to the development of Dr.REX—an apparatus for recovering eyesight by using a stereoscopic video. In this study, we verified the effects of this apparatus on visual acuity and asthenopia in the short and medium terms. Thirty-two myopic Japanese students participated in this study. We compared the severity of asthenopia in subjects who used Dr.REX and in those who performed close work on video display terminals (VDTs). We determined that the use of the apparatus improved visual acuity in both the short and medium terms. In addition, asthenopia seemed to be less severe in subjects who used Dr.Rex than in those who performed close work on VDTs.

Keywords: Pseudomyopia, visual acuity, asthenopia, stereoscopic video, visually induced motion sickness (VIMS).

1 Introduction

With the development of computers and the widespread use of the Internet, an increasing number of people need to perform close work (CW) such as operations on video display terminals (VDTs). Working under such conditions for many hours induces the contraction of the muscles involved in focus-adjustment around the eyeball, such as the ciliary body and extraocular muscles. Thus, it is possible that CW impairs focus adjustment—a symptom known as pseudomyopia [1]. In addition, CW has also been reported to induce cervicobrachial syndrome and psychoneurotic syndromes [2], [3].

Pseudomyopia is a symptom of refractive myopia. Relaxation of the contracted muscles involved in focus-adjustment is expected to alleviate pseudomyopia. An eyesight-recovering apparatus called MD-SS [4], developed by Kobayashi [5], is used to relax the contracted muscles. This apparatus works by using a Landolt ring drawn on a flat plate that moves back and forth over a distance of 2 m. Although the use of this apparatus is an effective way to improve eyesight, it is not an efficient solution because trainees are required to visit the clinic to use the apparatus, and hence, many

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trainees discontinue the training. The apparatus is also very expensive and large for trainees to buy privately. However, a new apparatus that delivers similar results was recently developed by Olympus Visual Communications [6]. This apparatus, called Dr.REX, uses stereoscopic video to overcome the problems associated with the old apparatus. In this paper, we verify the effect of this apparatus on visual acuity and asthenopia in the short and medium terms by conducting tests on myopic youths.

2 Materials and Methods

2.1 Outline of the Eyesight Recovering Stereoscopic Movie System

Dr.REX consists of a general-purpose personal computer, glasses with liquid crystal shutters, a liquid crystal display (LCD), a pair of speakers, and movie contents. We prepared images of a ball for the right and left eyes (Fig. 1). Each image was created using the POWER-3D method developed by Olympus Visual Communications. By simultaneously adjusting convergence, binocular parallax, and focus, the human eye can perceive images in three dimensions. A general stereoscopic image of an artificial object was constructed using fixed line of sight and without adjusting for convergence. Due to these measures, visually induced motion sickness (VIMS) occurred only infrequently [7]. However, images based on the POWER-3D method were constructed such that the contradiction between the experimental observations and actual conditions could be reconciled. Viewing the stereoscopic images effectively prevented VIMS in the observers. The right and left liquid crystal shutters in the glasses (Fig. 2) opened and shut in a synchronized fashion when the subjects viewed the images on the LCD. Furthermore, the right and left eyes alternately focused on each image. Hence, observers could perceive the images as a smooth stereoscopic movie at 60 Hz. The stereoscopic ball was first presented near the glasses and then moved far away from the glasses. As the movie was gradually moved closer or further away from the glasses, greater effort was required to adjust to the movie image on the LCD. Consequently, the muscles around the eyes were stimulated in such a way that observers could detect an improvement in their eyesight.

Apart from playing stereoscopic movies, Dr.REX also plays music, which had a relaxing effect on the observers. In this way, Dr.REX has not only a training effect on the observers but also a relaxing effect and thus attempts to improve eyesight using both physical and psychological methods.

2.2 Methods

A total of 32 myopic Japanese students (age, 20 ± 1 years; 16 men and 16 women) voluntarily participated in this study after signing informed consent forms.

The study participants were divided into 2 groups. Before the commencement of the study, we measured the far vision of the subjects by testing both eyes, right eye and left eye individually and simultaneously using the automatic optometer NV-300 (Nidek) (Pre). If the visual acuity, as measured by the automatic optometer, was <0.1, the visual acuity was measured using a Landolt chart posted on a wall. The protocol of this study is shown in Table 1. Under a controlled environment (mean illuminance: 240 lux, room temperature: 24 °C), the subjects in 1 group used the Dr.REX apparatus for 6 min; the subjects in the other group carried out CW on VDTs, which required them to maintain a steady gaze for the same amount of time. Each group carried out their assigned tasks every day for 11 days. Far-vision tests were carried out, and eye-strain was quantified using the visual analog scale (VAS[1]) immediately after loading. On days 5 and 11 (the final day), we made an addition to the far-vision tests before loading and filling out a simulator sickness questionnaire [8] (SSQ[2]) before and after loading. The degree of asthenopia calculated the SSQ was defined as SSQ-OD.

Fig. 1. An image produced using the POWER-3D method. The next image for the other eye is laterally shifted by a few centimeters due to the angle of convergence. An observer using glasses with liquid crystal shutters perceives the images in three dimensions.

Fig. 2. An observer uses the specially designed glasses. The right and left liquid crystal shutters in the glasses alternately open and shut at a frequency of 30 Hz. If the observer is myopic and cannot see the LCD without glasses, he/she wears both the glasses for myopia correction and the glasses with liquid crystal shutters.

[1] VAS, a visual assessment scale, is a 95-mm-long linear scale prepared such that moving the scale to the right increases the degree of asthenopia.

[2] Subscores were derived from the SSQ to measure the degree of VIMS. SSQ-OD was used to evaluate the degree of asthenopia.

Table 1. Study protocol. One group performed close work, and the other used the Dr.REX apparatus. The assignments were then switched between the groups, and the same protocol was followed. We intend to indicate results of an auto refractmeter in a next report.

<table>
<tr><th>Day</th><th>1-4</th><th>5</th><th>6-10</th><th>11</th></tr>
<tr><td rowspan="3">Protocol</td><td>Load 1*
or
Load 2**</td><td>SSQ*****
Auto Refractometer
Far-vision</td><td>Load 1
or
Load 2</td><td>SSQ****
Auto Refractometer
Far-vision</td></tr>
<tr><td rowspan="2">VAS***
Far-vision****</td><td>Load 1
or
Load 2</td><td rowspan="2">VAS
Far-vision</td><td>Load 1
or
Load 2</td></tr>
<tr><td>SSQ
VAS
Auto Refractometer
Far-vision</td><td>SSQ
VAS
Auto Refractometer
Far-vision</td></tr>
</table>

* Load1: Close work on video display terminals
** Load2: Using the Dr.REX
*** Visual Analog Scale
**** Far-Vision was mesured without glasses.
***** Simulator Sickness Questionnaire

Each group was required to take a 2-week break to expect the effects of loadings. The assignments were then switched, and the study was resumed with the same protocol. Thus, we obtained 32 datasets controlled the loading order.

3 Results

3.1 Visual Acuity

First, the geometrical mean of the visual acuity of the subjects before and after using Dr.REX on days 5 and 11 is shown in Table 2; these values were used to verify the short-term effects of the training. The visual acuity increased after using the apparatus on both days 5 and 11. Using the Wilcoxon matched-pairs signed-ranks test, a significant difference was found in the visual acuity of both eyes on day 11 and the left eye on days 5 and 11 ($P < 0.05$).

Next, in order to verify the effects in the medium term, the geometrical means of the visual acuity of the subjects after they had used the Dr.REX apparatus and performed CW are shown in Fig. 3-a and Fig. 3-b, respectively. The geometrical mean of the visual acuity was higher after using Dr.REX than it was before using this apparatus. The Friedman test revealed significant variations in the visual acuity in the all cases ($P < 0.01$) (Fig. 3-a). In addition, multiple comparisons showed significant differences in the pre- and post-test visual acuity of the right eye on days 8, 9, and 11 and of the left eye on days 8, 10, and 11 ($P < 0.05$). The Friedman test was also used to evaluate the differences in visual acuity after performing CW; no significant variations were found in the visual acuity.

3.2 Asthenopia

The degree of asthenopia was measured using the VAS. Significant variations in the VAS scores were not found in the short or medium term. In contrast, significant variations in the SSQ-OD scores were noted in the short term but not in the medium term. The mean SSQ-OD scores before and after using Dr.REX and performing CW on days 5 and 11 are shown in Table 3. The scores increased after each loading on both days. Using the paired *t* test, a significant difference was found only performing CW on day 5 ($P < 0.01$).

Table 2. Changes in the mean of visual acuity after using the Dr.REX apparatus on days 5 and 11. On both days, the visual acuity increased after the training.

Schedule (day)	5 (Before)	5 (After)	Increase	11 (Before)	11 (After)	Increase
Both eyes	0.145 ± 0.284	0.160 ± 0.282	0.015	0.138 ± 0.269	0.171 ± 0.267*	0.033
Right eye	0.114 ± 0.273	0.123 ± 0.272	0.009	0.126 ± 0.272	0.138 ± 0.246	0.012
Left eye	0.089 ± 0.440	0.106 ± 0.260*	0.017	0.101 ± 0.242	0.120 ± 0.240*	0.019

*$P < 0.05$

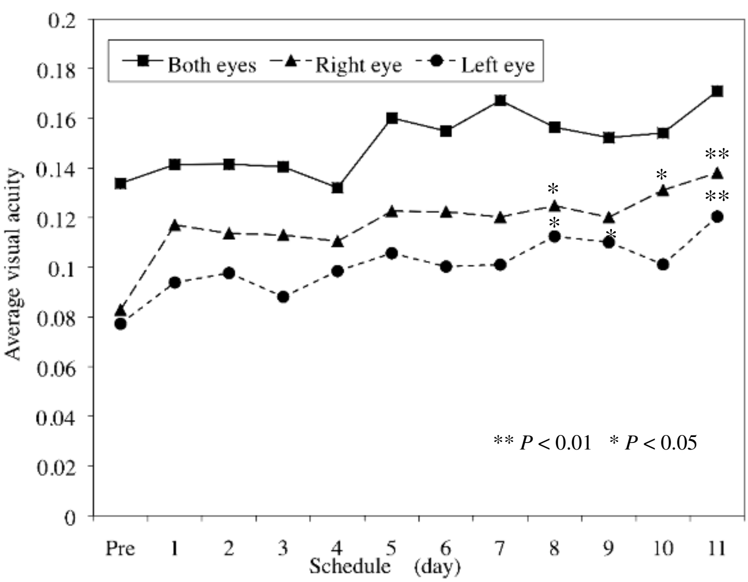

Fig. 3-a. Changes in the geometrical mean of visual acuity after using the Dr.REX apparatus

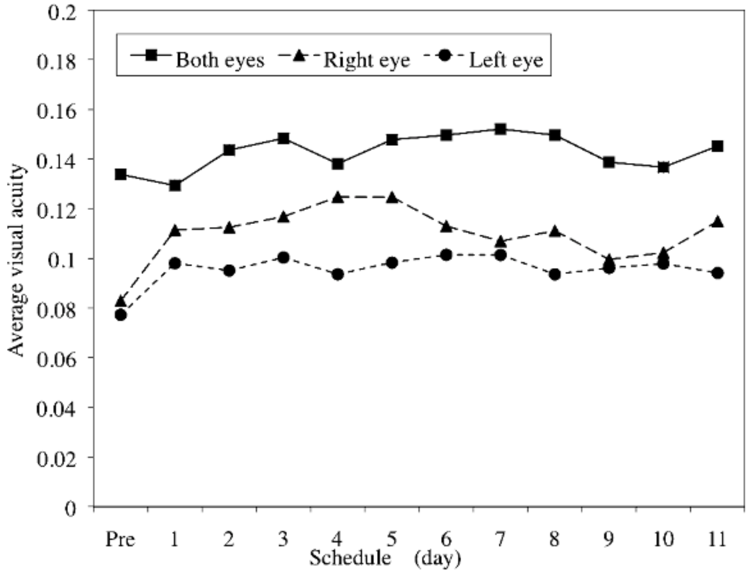

Fig. 3-b. Changes in the geometrical mean of visual acuity after performing close work

Table 3. Changes in the mean SSQ-OD scores before and after loadings on days 5 and 11. The scores increased after all loadings.

Schedule (day)	5 (Before)	5 (After)	Increase	11 (Before)	11 (After)	Increase
Dr.REX	4.26 ± 2.18	6.63 ± 2.25	2.37	5.92 ± 2.38	7.11 ± 2.28	1.18
CW	6.16 ± 2.08	9.71 ± 2.41**	3.55	5.92 ± 2.57	7.34 ± 2.68	1.42

**$P < 0.01$, CW: close work.

4 Discussion

4.1 Visual Acuity

First, the short-term effects of the apparatus on visual acuity were verified on the basis of the results of the far-vision tests on days 5 and 11. An improvement in visual acuity was noted so that the some mean of the visual acuity were increased. However, the increase in visual acuity was not significant for all the conditions shown in Table 2. The reason for the differences in the degree of improvement in visual acuity was the condition of the subjects' eyes. Subjects who strained their eyes before the measurements experienced the largest improvements since their muscles involved in focus-adjustment were strongly contracted. In contrast, subjects whose muscles were already relaxed experienced hardly any improvement.

Next, the effects of apparatus on visual acuity in the medium term were verified on the basis of the results of the far-vision tests performed over a period of 11 days. The increase in the visual acuity on the final day (day 11) considerably exceeded that in the pre-tests. Further, the difference in visual acuity was statistically significant. Thus, we concluded that an improvement in visual acuity was more effective in the medium term than in the short term so that the muscles involved in focus-adjustment, such as the ciliary body and extraocular muscles, are stimulated continuously. Moreover, we compared effects of the Dr.REX with the CW in Fig. 3. Visual acuity measured after loadings were a significantly difference on day 11 by using the Wilcoxon matched-pairs signed-ranks test ($P < 0.05$). This result suggests that the Dr.REX apparatus has a cumulative positive effect on eyesight and prevents the deterioration of visual acuity. After using this apparatus, some subjects experienced a large improvement in visual acuity, while others only experienced a slight improvement. We consider that the differences in the degree of improvement were attributable to differences among individuals.

4.2 Asthenopia

The differences in the degree of asthenopia after using Dr.REX and performing CW were verified on the basis of the asthenopic scores (VAS and SSQ-OD).

First, we evaluated the VAS scores after the subjects used Dr.REX and performed CW. The mean values for 11 days are shown in Fig. 4. The mean VAS scores after using Dr.REX were lower than the scores after performing CW. Further, a paired t test revealed that the difference in the scores was significant ($P < 0.01$).

With regard to the SSQ-OD scores, the mean score after performing CW was higher than that after using Dr.REX, but the difference was not significant. Since the assessment was subjective, we consider that these results depended on each subject's psychological condition or on the condition of the eyes.

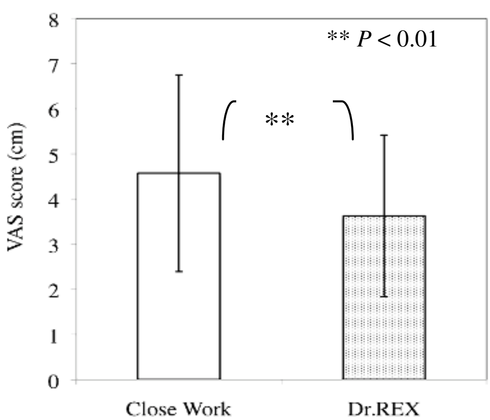

Fig. 4. Mean visual analog scale (VAS) scores after using the Dr.REX apparatus and after performing close work (CW). The mean VAS score after using the Dr.REX (0.948) is lower than that after performing CW.

The manufacturer of the Dr.REX apparatus recommends that the apparatus be used for 10 minutes at a time. Thus, in this study, we expected the degree of improvement in asthenopia to be low because the subjects were instructed to use the apparatus for only 6 min. Dr.REX had a relaxing effect on the subjects and a compulsory stretching effect on the muscles involved in focus-adjustment. We consider that these effects transiently induced asthenopia. On the other hand, the CW in this study was designed to induce asthenopia, and we consider that it did so in all the subjects. Thus, we estimated that asthenopia resulting from CW was more severe than that resulting from using Dr.REX. This conclusion, however, needs to be verified.

5 Conclusion

This study proves that pseudomyopia can be improved by relaxing the contracted muscles involved in focus-adjustment, such as the ciliary body and the extraocular muscles, by using a stereoscopic movie shown on an LCD. Furthermore, the apparatus used to present the movie, Dr.REX, is inexpensive and compact, as previously mentioned. With this apparatus, trainees are less likely to discontinue the training. Therefore, we conclude that the continual use of this apparatus improves visual acuity by relaxing contracted muscles involved in focus-adjustment.

Asthenopia induced by CW is more pronounced than that induced by the use of Dr.REX. However, no significant improvement of asthenopia was observed with the use of the Dr.REX apparatus. These results must be verified using other indexes of asthenopia.

In the future, we suggest that the apparatus be used for several months in order to verify its long-term effects on visual acuity and asthenopia. In addition, we intend to perform this study on older myopic people, and middle-aged and elderly presbyopic people.

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