Evaluation of a novel dichoptic training method using polarising film for treatment of amblyopia

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Research Article

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Abstract

We have developed a new, low-cost, easily administered method that uses a polarising film to enable dichoptic training for amblyopia. In this study, we compared its effects with occlusion therapy using an eye patch. Fifty-eight patients (4.7 ± 0.1 years old) diagnosed with anisometric amblyopia were included and instructed to wear complete refractive correction glasses with either occlusion therapy using an eye patch (eye patch group) or dichoptic training using polarising film (polarising film group) for two hours per day. We examined the improvement in the visual acuity and adherence rate of the patients two months after treatment initiation. After training, the polarising film group showed significant improvement in visual acuity compared with the eye patch group. The adherence rate was also significantly better in the polarising film group than in the eye patch group. In both groups, there was a significant correlation between the improvement in visual acuity and adherence rate. This new dichoptic training using a polarising film was shown to be effective for anisometropic amblyopia.

Introduction

Amblyopia is a disease in which visual acuity remains poor despite refraction correction and the absence of organic disease. Its prevalence varies across geographical locations has been reported to be approximately 1–2% [1, 2]. Furthermore, amblyopia is a common cause of visual impairment in children and occurs approximately 10 times more frequently than other eye diseases, such as retinopathy of prematurity, optic nerve atrophy, and nystagmus, in childhood [3].

The first choice for amblyopia treatment is wearing of eyeglasses for complete refraction correction; however, it has been reported that wearing spectacles cures only approximately 30% of patients [4]. Therefore, occlusion therapy using an eye patch is most commonly used as an additional treatment [5]. It aims to improve visual acuity through forcible use of the amblyopic eye by blocking the healthy eye. However, occlusion therapy has side effects, including occlusion amblyopia, mental distress, and skin irritation [6, 7]. Given that occlusion therapy has low adherence, it is administered only for approximately 50% of the prescribed occlusion time [8, 9]. Furthermore, it has been reported that adherence decreases with an increase in the treatment period [10].

In recent years, dichoptic training has been developed to treat amblyopia. In this training, visual stimuli are presented separately to the healthy and amblyopic eyes. It is known that in patients with amblyopia, the difference in the visual acuity of the amblyopic and healthy eyes increases with suppression, which worsens stereoscopic vision [11]. Devices for dichoptic training for amblyopia reduce interocular suppression and aim to improve visual acuity and stereoscopic vision through tasks, such as games, by unifying the input balance from each eye, enabling the integration of visual information from each eye [12]. Several types of dichoptic training devices have been developed for amblyopia, including digital devices such as tablet terminals, smartphones, and head-mounted displays [13–17]. The environment for amblyopia training is limited because these devices require specialised equipment, processing, and specialised applications. Furthermore, since these electronic devices are expensive, they are difficult to

procure compared to an eye patch, which creates the need to develop a more affordable and easy-to-use dichoptic training device for amblyopia [18]. Therefore, in this study, we examined the usefulness and efficacy of an inexpensive and easily administered dichoptic training method for amblyopia using polarising films devised by us.

Results

There were no significant differences in patient age, anisometropia, and visual acuity between the eye patch and polarising film groups (p = 0.26, p = 0.95, p = 0.18) before training for amblyopia (Table 1). The mean age, anisometropia, and amblyopic visual acuity were 4.8 ± 1.0 years, 3.24 ± 0.66 diopter, and 0.26 ± 0.10, respectively, in the eye patch group before training. The mean age, anisometropia, and amblyopic visual acuity were 4.5 ± 1.0 years, 3.23 ± 0.64 diopter, and 0.30 ± 0.11, respectively, in the polarising film group before training.

Table 1
Patient characteristics before training for amblyopia

	Age (years)	Anisometropia (Diopter)	Visual acuity
Eye patch group	4.8 ± 1.0	3.24 ± 0.66	0.26 ± 0.10
Polarising film group	4.5 ± 1.0	3.23 ± 0.64	0.30 ± 0.11

The visual acuity of the eye patch and polarising film groups after training for amblyopia was 0.17 ± 0.10 and 0.13 ± 0.10, respectively, with visual acuity improvement of -0.08 ± 0.07 and − 0.17 ± 0.07, respectively. The polarising film group showed significant improvement in visual acuity compared to that in the eye patch group (p < 0.0001) (Table 2). The adherence rates of the eye patch and polarising film groups were 68.8% ±18.8% and 85.3 ± 15.4%, respectively, with significantly better values in the polarising film group (p = 0.002) (Table 2). A significant correlation was found between the improvement in visual acuity and adherence rates in both groups (eye patch group: p = 0.003, r=-0.47; polarising film group, p = 0.002, r=-0.67) (Fig. 1).

Table 2
Comparison of visual acuity before and after training for amblyopia in both groups

	Visual acuity before training	Visual acuity after training	Visual acuity improvement	Adherence rate (%)
Eye patch group	0.26 ± 0.10	0.17 ± 0.10	-0.08 ± 0.07	68.8 ± 18.8
Polarising film group	0.30 ± 0.11	0.13 ± 0.10	-0.17 ± 0.07	85.3 ± 15.4

Discussion

In this study, we administered dichoptic training using polarising films to patients with amblyopia. Several dichoptic training methods for amblyopia have been developed so far [13–17], but all devices require specialised devices and applications. Therefore, visual stimuli used for amblyopia training are limited and expensive, making it difficult to provide these to all patients, unlike eye patches. However, the method developed by us enables dichoptic training for amblyopia even on digital devices such as TVs, tablet terminals, smartphones, and paper media such as books in the patient's own home. Moreover, since the polarising film is inexpensive, it can be easily provided to all patients.

In this study, the training for amblyopia using polarising films showed a significant improvement in visual acuity compared with occlusion therapy for amblyopia using an eye patch. Dichoptic training for amblyopia is expected to have a better effect than occlusion therapy for amblyopia, some studies have reported its superiority[13, 19–21]. However, some studies have reported no difference between the two methods, making it difficult to reach a definite conclusion [14, 22, 23]. Further, it has been reported that dichoptic training does not completely block the healthy eye like the eye patch, which decreases mental burden and maintains adherence [13, 15]. In the present study, superior adherence to dichoptic training was observed. We were unable to determine if the superior visual acuity of this method compared to those treated with the eye patch was a result of the differences in the principles of dichoptic and occlusion therapy or the difference in adherence to the treatment. Although the improvement in visual acuity was 2.1 times higher in the polarising film group than in the eye patch group, the difference in terms of the adherence rate remained at 1.2 times (85.3/68.8). Based on these results, it is possible that dichoptic training is more effective than occlusion therapy. However, since the adherence in this study is based on self-reported data by the patient, it cannot be denied that the values may deviate from the actual values. In the past, it has been pointed out that the adherence values reported by patients deviate from actual values [10].

This study has limitations. The risk of bias cannot be ruled out as the patients selected the training method. Moving forward, we believe it is necessary to conduct a randomised controlled trial with reference to this study and to study dichoptic training for amblyopia in further details using polarising films.

Methods

We developed a new dichoptic training method for amblyopia using polarising films. When two sheets of polarising film are stacked to create a perpendicular absorption axis, only the overlapping portion of the polarising film prevents light from passing through and occludes the vision (Fig. 2). One sheet of polarising film was attached to the target used for the training; the target was not limited to electronic devices such as televisions and tablet terminals, but also included paper media such as picture books. Using a clip, another polarising film with the absorption axis rotated 90°was attached to the training glasses on the side of the patient’s healthy eye (Fig. 3). As a result, the healthy eye was unable to see the portion to which the polarising film was attached at the target, which could only be seen with the amblyopic eye (Fig. 4). This method therefore made dichoptic training for amblyopia easy and affordable

without limiting the targets that could be used. For each patient, one polarising film attached to eyeglasses and five polarising films of different sizes attached to the target were provided (60 × 106 cm, 40×71 cm, 30×53 cm, 20×36 cm, and 7x12 cm). If the size of the polarising film did not fit, the patient was instructed to cut and attach the polarising film according to the fit.

The study included patients diagnosed with anisometropic amblyopia visiting our hospital between April 2019 to April 2021. The following selection criteria were applied: patient age ≥ 3 and ≤ 8 years with anisometropia of at least 2.00 diopter at equivalent spherical power under accommodation paralysis and a maximum visual acuity of a logMAR value of 0.1 or less in the affected eye. The exclusion criteria were as follows: astigmatism of at least 1.50 diopter, heterophoria of at least 15Δ, strabismus, a history of amblyopia treatment, and difficulty in performing the examination. This study was approved by the Ethics Review Board of Kitasato University School of Medicine/Hospital and was performed in accordance with the tenets of the Declaration of Helsinki. Informed consent was obtained from all participants and a legal guardian. The participants underwent either occlusion therapy using an eye patch or dichoptic training for amblyopia using polarising films and were free to choose between the two methods.

Training for amblyopia using eye patches (eye patch group) was performed on 34 of the 58 participants (4.7 ± 0.1 years, 3–7 years). In addition, dichoptic training for amblyopia using polarising films (polarising film group) was performed in 24 cases.

All patients were instructed to use fully refraction-correcting spectacles prescribed for accommodation paralysis with cyclopentolate hydrochloride. The eye-patch group was instructed to undergo occlusion therapy using an eye patch for two hours per day. During the training for amblyopia, there were no restrictions on watching videos, reading books, or playing other games. The polarising film group was instructed to undergo dichoptic training for amblyopia using polarising films for two hours per day. During the training for amblyopia, the patients were instructed to watch TV, use tablet terminals and smartphones, and read books, with a poliarising film. All patients were instructed to record the duration (minutes) of training for amblyopia performed per day (adherence). We compared the visual acuity improvement two months after the start of training for amblyopia, the adherence rate [(training implementation time/training instruction time)×100] for the amblyopia training, and the correlation between visual acuity improvement and adherence rate.

The Mann-Whitney U test was used to compare the eye patch group and the polarising film group. The Kendall rank correlation coefficient was used to correlate the visual acuity improvement values with the adherence rate. The normality of the data was confirmed using the Kolmogorov-Smirnov test. Statistical significance was set at $P < 0.05$.

Declarations

Data availability:

The all data used to support the findings of this study are available from the corresponding author upon request.

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Author contributions:

The study was approved by the Institutional Review Board at Kitasato University School of Medicine. The authors were involved in the design and conduct of the study (Y.I., T.H.); collection, management, analysis, and interpretation of data (Y.I., T.H.); preparation of manuscript (Y.I.), critical revision of manuscript (T.H., H.I.) and final approval of manuscript (Y.I., T.H., H.I.).

Competing interests: the authors declare no competing interests.

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Figures

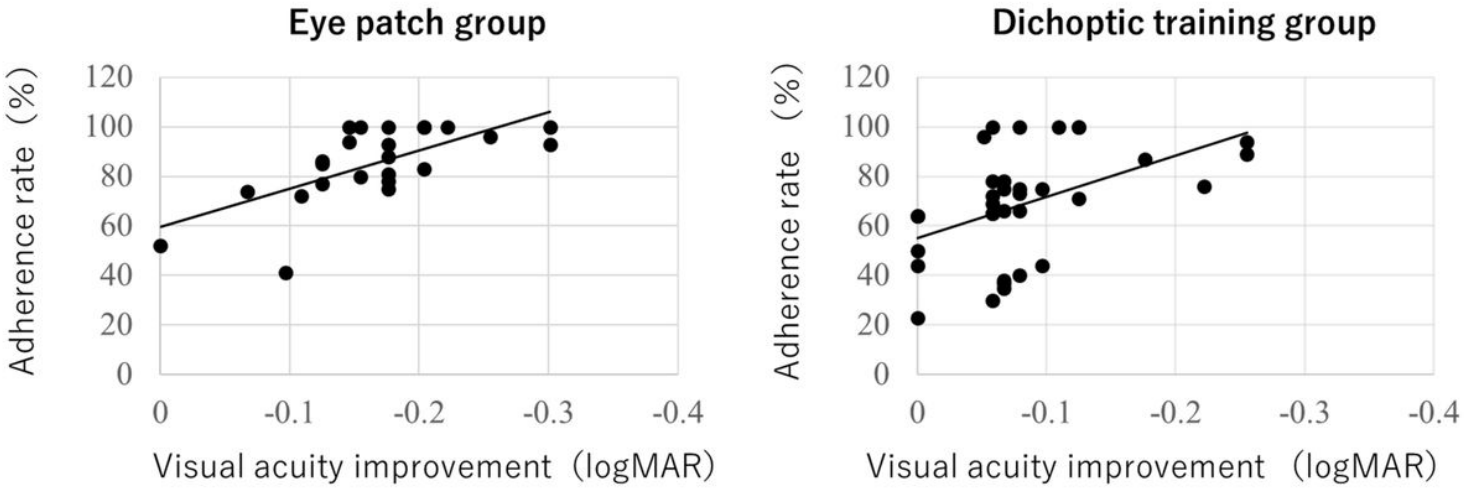

Figure 1

Correlation between the visual acuity improvement and adherence rate There was a significant correlation between the visual acuity improvement and the adherence rate in both study groups.

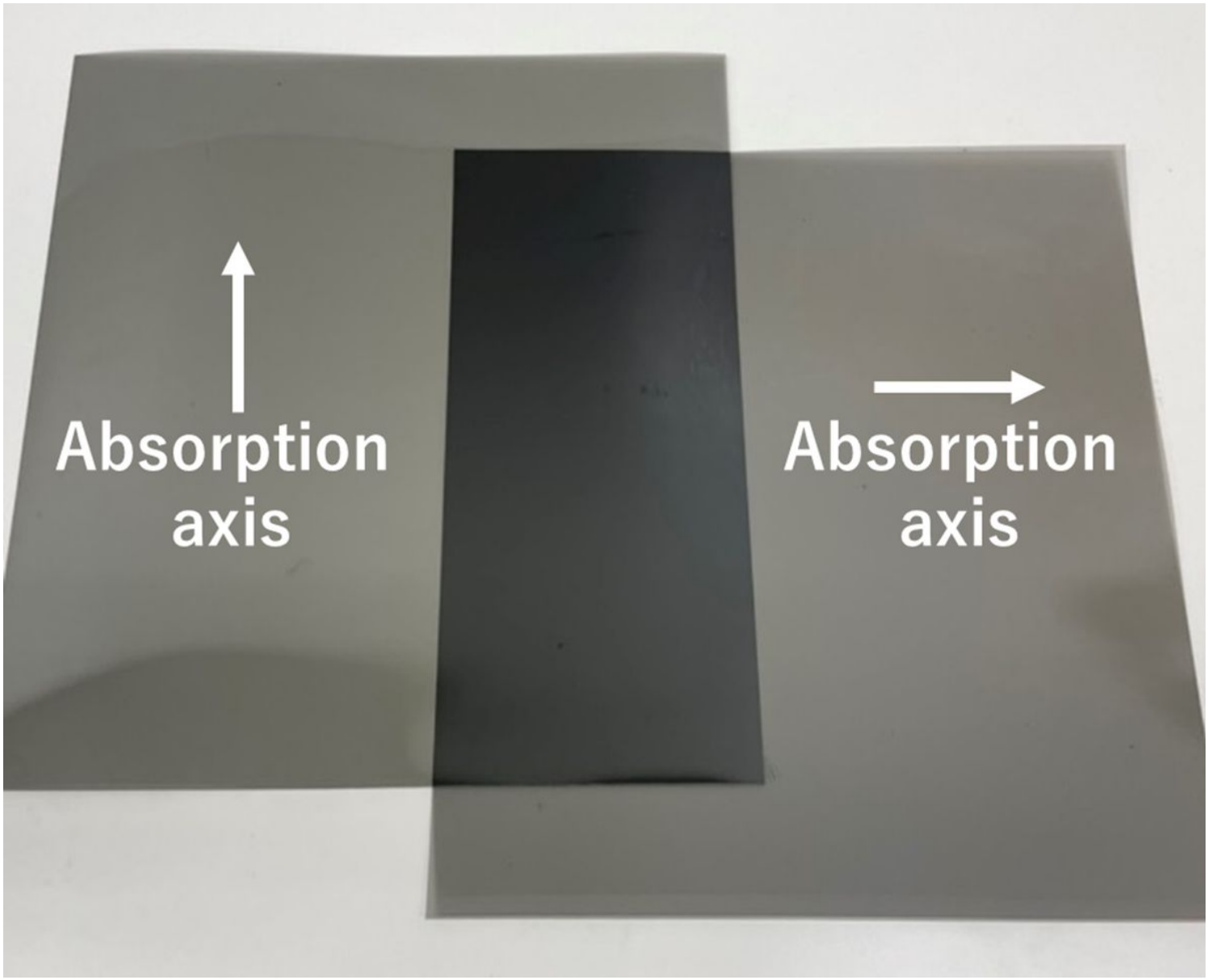

Figure 2

Underlying principle of the dichoptic training method applied in this study. Light is unable to pass through two polarising films when their absorption axes overlap such that they are perpendicular to each other.

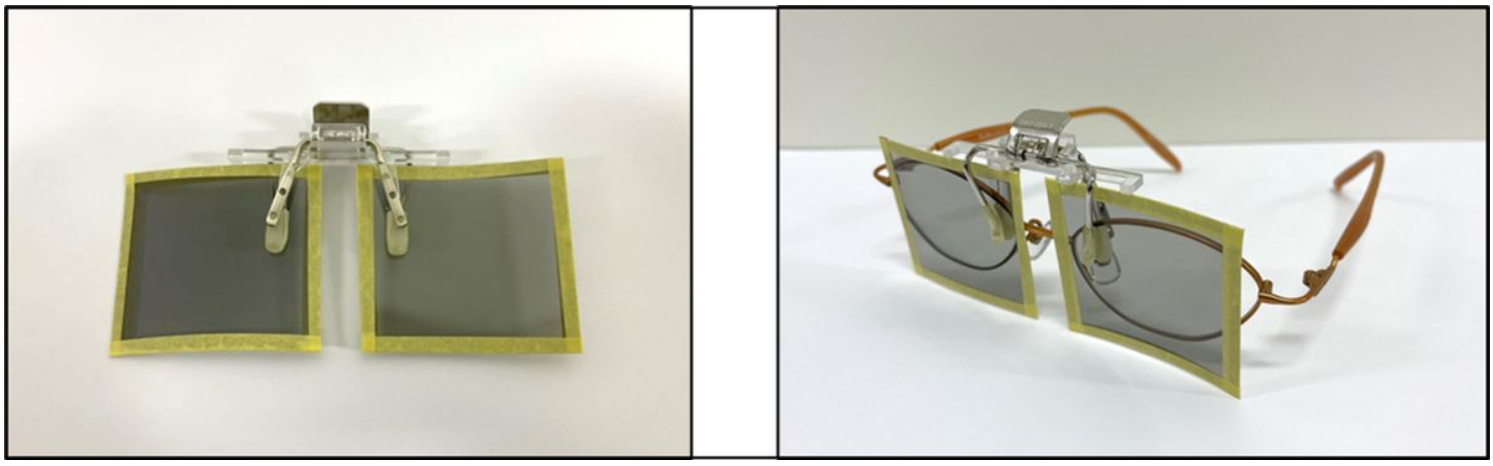

Figure 3

Polarising film attached to the eyeglasses. The film can be easily attached to the eyeglasses using a clip.

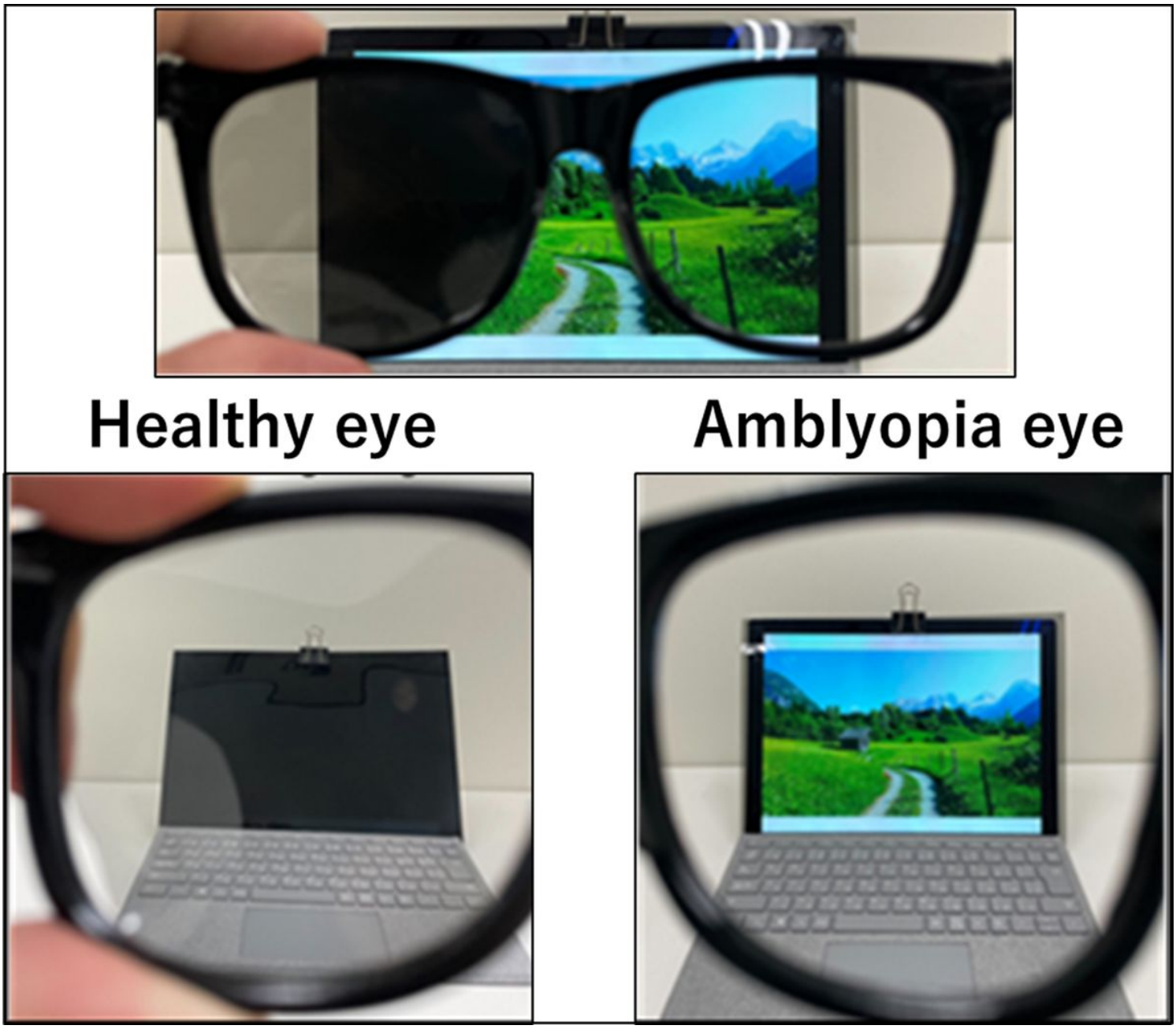

Figure 4

Dichoptic training method used in the study. A polarising film is attached to the monitor for amblyopia training, and another polarising film is also attached to the eyeglasses on the healthy eye side so that the absorption axes of the films are perpendicular to each other. No polarising film is attached to the side of the eye with amblyopia. By doing so, only the eye with amblyopia is able to see the monitor when both eyes are open.