Effect of Accommodation Training on Visual Function of Middle-Aged People

Yasuyuki Matsuura, Masumi Takada, Masaru Miyao, and Hiroki Takada

***Abstract*—By relaxing the contracted focus-adjustment muscles around the eyeball, such as the ciliary and extraocular muscles, improvement of the pseudo-myopia is expected. This understanding has led to the accommodation training in which the visual target is given by stereoscopic video clips. In this study, we verify effects of the apparatus on eyesight of 12 middle-aged persons. The middle-aged were investigated on several trials of the eyesight recovering apparatus. As a result, the visual acuity was statistically improved by continuous accommodation training which will promote a ciliary muscle-stretching effect.**

***Index Terms*—3D movie, visual function, middle-aged people.**

I. Introduction

With the development of computers and widespread use of the internet, near visual tasks, such as visual display terminal (VDT) activities, have increased in young to elderly persons, causing social problems. Near visual tasks for a prolonged time strain the ciliary muscle, which may cause abnormalities in the accommodative function of the lens. This condition is called pseudomyopia, considered to be a part of refractive myopia. Prolonged near visual tasks have been reported to possibly induce cervico-omo-brachial syndrome and psychoneurotic symptoms [1]. The main cause of these vision problems is an accommodative function error. Therefore, we assume that it is possible to improve an abnormal accommodative function of the lens by activating the muscles by alternately repeating negative and positive accommodation. By improving the abnormal accommodative function, we can improve or prevent these vision problems. We call this operation "accommodation training." In Japan, an apparatus called MD-SS was developed [2]. This apparatus works by using a Landolt ring drawn on a flat plate that moves back and forth over a distance of 2 m in order to encourage alternately repeating negative and positive accommodation in the observers. However, the moving distance of the target object is very short. Therefore, the back-and-forth motion of the objects might have no effect on the observers. In order to solve the abovementioned problems, we suggest that the accommodation training is accomplished by gazing at an image in 3D movies, which simulate the back-and-forth motion in a stereoscopic space by using a computer and a liquid crystal display (LCD).

For pseudomyopia, stretching exercise of the ciliary muscle, involved in accommodation of the lens, by alternately repeating negative and positive accommodation alleviates strain of the ciliary muscle, and temporarily improves the myopic condition. Miyao *et al*. experimentally showed that the lens was accommodated by following stereoscopic images when gazing at them displayed on a CRT or LCD [3], [4].

Presbyopia represents senile impairment of near vision due to a reduced accommodative function of the lens with aging. The major cause of the reduction of accommodative function is thickening of the lens with aging, increasing the radius of the frontal curvature of the lens. In addition to this increase in lens volume, the elasticity of the lens capsule decreases, which results in an insufficient increase in the lens curvature even when the ciliary zonule is relaxed by ciliary muscle contraction, reducing the amplitude of accommodation [5].

Stereoscopic videos utilizing binocular stereoscopic vision often cause unpleasant symptoms of asthenopia, such as headache and vomiting, depending on the audiovisual condition [6]. Ataxia in simulator-induced sickness has been reported. The influence of video-induced motion sickness on the body has been measured employing subjective scales, such as the Simulator Sickness Questionnaire (SSQ) [7], and by quantitatively investigating the relationship between external factors and internal conditions using physiological indices [8]-[11], such as respiratory function, electrocardiogram, skin electrical activity, fluctuation of the center of gravity, and electrogastrogram.

A new 3D video construction method has recently been developed to prevent video-induced motion sickness [12], [13]. Humans perceive 3-dimensional objects by simultaneous convergence and accommodation of the lens, but stereoscopic videos generally consist of unnatural images perceived along a fixed visual line, negating such convergence and accommodation. Stereoscopic images using the POWER3D method (Olympus Visual Communications Co., Ltd.) prepared in order to reduce inconsistency between experience and the actual senses [14]. Some preceding studies showed that the degree of sickness was reduced by viewing stereoscopic videos prepared using this method [15], [16]. We focused on stereoscopic videos prepared using this method. An LCD displaying the stereoscopic videos and visual acuity recovery device utilizing liquid crystal shutter eyeglasses (DR.REX Eye Care Program [14]) include several

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stereoscopic video contents, which induce near and distant visual conditions. The alternating presentation of these with appropriate intervals is expected to employ accommodation prevent myopia and presbyopia.

In this study, we investigated the visual acuity-improving effect of the device utilizing stereoscopic training and middle-aged subjects becoming aware of presbyopia.

II. Material and Method

The objective and contents of the study and consideration of protection of personal information were explained to all subjects before the experiment, and written informed consent was obtained. The measurement was performed in a dimly lit room (about 260 lx) air-conditioned at 25℃.

The subjects were 12 middle-aged persons aged 46.6 ±3.5 years (6 males and 6 females). The accommodation training was performed, in which the subjects viewed 4 contents of the DR.REX Eye Care Program for 6 minutes each in a random order. Before the accommodation training and after viewing each of content, the tests:

1) Simulator sickness questionnaire (SSQ)
2) Visual analog scale (VAS)
3) Objective refractometry
4) Uncorrected visual acuity test (distant vision)
5) Uncorrected visual acuity test (near vision)
6) Accommodative function test

were performed in this order. The auto visual acuity meter NV-300 (NIDEK) was used for the uncorrected visual acuity test which was employed for binocular and monocular (left) visions. The subjects then viewed the 4 contents in the same order for 6 minutes each, and the above tests were repeated. Time-course changes in the uncollected visual acuity at a distance and from near were investigated. Findings on the visual acuity, the accommodative function test, and subjective scales such as the SSQ and visual analog scale (VAS) for before (Pre) and after viewing stereoscopic videos (Post) were compared employing the Wilcoxon signed-rank test, setting the significance level to 0.05.

III. Results

Changes in the uncorrected binocular near and distant visual acuities with the frequency of video viewing are shown in Fig. 1. The visual acuities were expressed by the log-MAR scale. The gravitational mean uncorrected binocular near and distant visual acuities of the 12 subjects increased with the viewing frequency from the 1st to the 8th Post viewing, although there was some variation. On comparison of the uncorrected near visual acuity between the Pre and after the 7th video viewing employing the Wilcoxon signed-ranks test, a significant difference was noted (p<0.05). The same significant difference was noted in the near point accommodation (Fig. 2).

Subjective indices did not significantly increase with viewing frequency. The time-course changes in the VAS were shown in Fig. 3. The degree of asthenopia tended to decrease at 5th and 7th post viewing than that measured at Pre viewing (p<0.10).

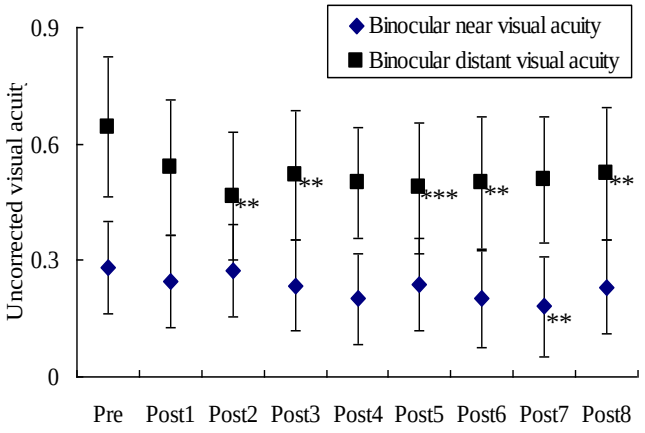

Fig. 1. Time-course changes in uncorrected binocular near and distant visual acuities (**p<0.05, ***p<0.01).

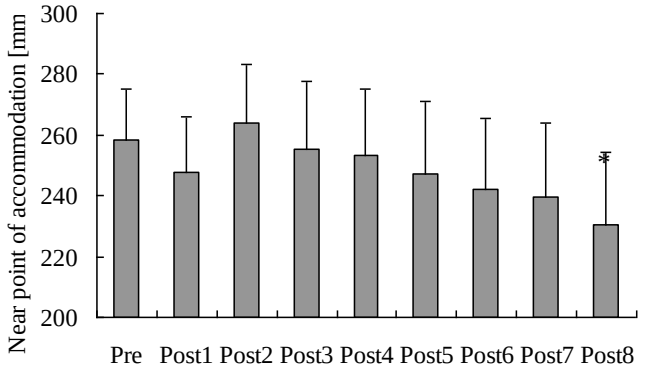

Fig. 2. Time-course changes in the monocular near point of accommodation (*p<0.10).

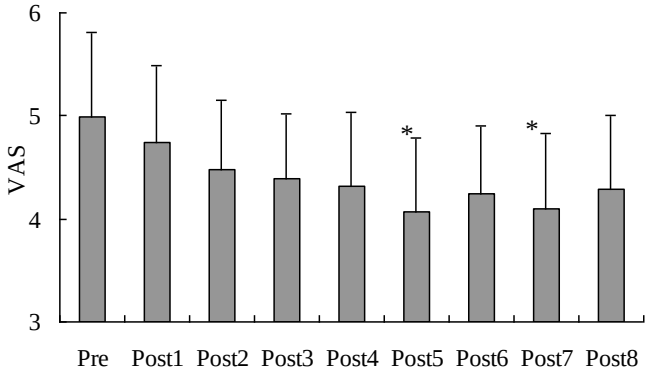

Fig. 3. Time-course changes in the VAS (*p<0.10).

IV. Discussion

In this study, the motions sickness could not be induced by viewing 3D video clips in accordance with subjective tests. We have presented a movie using the POWER 3D method as the movie for the accommodation training. The visual acuity was significantly improved by continuous accommodation training (Fig. 1).

The mean spherical diopter was about –3 diopters in both eyes, showing no significant changes with the viewing frequency in the accommodation training [17]. We assumed that the effect of the accommodation training was temporary, but the findings suggest that the continuous use of DR.REX

will promote a ciliary-muscle-stretching effect, leading to an improvement in visual acuity. Accommodation reflex for near vision may be defined as the mechanism of working the ciliary muscle. This may also inhibit a reduction in the visual acuity.

The authors have verified the effect of accommodation training that uses the strategy of presenting a stereoscopic movie to 32 myopic youth (20±1 years). The movie consists of one to five balls moving back and forth in the stereoscopic sky background. At a viewing distance of 60 cm, the stereoscopic ball is viewed to move from 30 cm (forward) to infinity (backward). This ball completes a round-trip movement more than 25 times in 3 min. The uncorrected distant visual acuity increased in 17 of the 32 subjects (53.1%) participating in this study. Although there were some variations, the visual acuity improved in the accommodation training group and not in the control group. Upon comparing the value obtained on each measurement day using the Wilcoxon signed ranks test, we found that the visual acuity on day 11 was considerably higher in the accommodation group than in the control group ($p<0.05$). This result suggests that the accommodation training using a stereoscopic movie has a cumulative positive effect on eyesight and prevents the deterioration of visual acuity. Although the myopic tendency improved slightly in the accommodation training group, there was only slight progress in the control group. These results suggested that the accommodation training using the stereoscopic movie did not deform the lens, thus not improving myopia fundamentally [18].

We also verified short-term effects of this kind of the accommodation training on eyesight of visual inspection workers (22 females) suffering from eye fatigue [19]. The workers were trained in 3 days. As a result, the visual acuity was statistically improved by continuous accommodation training which will promote a ciliary muscle-stretching effect.

Both the uncorrected binocular near and distant visual acuities were improved (Fig. 1), suggesting that the viewing of the stereoscopic video reduced strain and increased the flexibility of the ciliary muscle, which temporarily recovered the visual acuity. In contrast, diopteric measurements did not change in either eye [17]. The duration of treatment may have been too short to modify the eyeball (lens) structure. It was suggested that the short-term repeated accommodation training increased the near visual acuity, for which the improvement and prevention of presbyopia may be expected.

V. Conclusion

The visual acuity-improving effect of the visual acuity recovery device utilizing stereoscopic videos was investigated in middle-aged subjects becoming aware of presbyopia, and the visual acuity was improved by continuous accommodation training. We are planning to investigate the effect of employed for a prolonged period.

References

[1] T. Nakazawa, Y. Okubo, Y. Suwazono, E. Kobayashi, S. Komine, N. Kato, and K. Nogawa, "Association between duration of daily VDT use and subjective symptoms," *Am. J. Ind. Med.*, vol. 42, pp. 421-426, 2002.

[2] S. Kobayashi, "Eye sight recovering apparatus," *Japan Patent*, vol. H6 - 339501, Dec 13, 1994.

[3] M. Miyao, S. Ishihara, S. Saito T. A. Kondo, H. Sakakibara, and H. Toyoshima, " Visual accommodation and subject performance during a stereoscopic object task using liquid crystal shutters," *Ergonomics*, vol. 39, no. 11, pp. 1294-1309, 1996.

[4] M. Omori, T. Watanabe, J. Takai, H. Takada, and M. Miyao, "A trial for preventing asthenopia among VDT workers," *Int. J. Occupational Safety and Ergonomics*, vol. 9, no. 4, pp. 453-462, 2003.

[5] T. Fukuda, "Aging and visual fuctions," *ITEJ technical report*, vol. 15, no. 3, pp. 1-8, 1991.

[6] K. Ukai and P. A. Howarth, "Visual fatigue caused by viewing stereoscopic motion images," *Displays*, vol. 29, pp. 106-116, 2008.

[7] R. S. Kennedy, N. E. Lane, K. S. Berbaum, and M. G. Lilienthal, "Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness," *Int. J. Aviation Psychology*, vol. 3, pp. 203-220, 1993.

[8] S. R. Holomes and M. J. Griffin, "Correlation between heart rate and the severity of motion sickness caused by optokinetic stimulation," *J. Psychophysiology*, vol. 15, pp. 35-42, 2001.

[9] N. Himi, T. Koga, E. Nakamura, M. Kobashi, M. Yamane, and K. Tsujioka, "Differences in autonomic responses between subjects with and without nausea while watching an irregularly oscillating video," *Autonomic Neuroscience: Basic and Clinical*, vol. 116, pp. 46-53, 2004.

[10] Y. Yokota, M. Aoki, and K. Mizuta, "Motion sickness susceptibility associated with visually induced postural instability and cardiac autonomic responses in healthy subjects," *Acta Otolaryngologia*, vol. 125, pp. 280-285, 2005.

[11] L. M. Scibora, S. Villard, B. Bardy, and T. A. Stoffregen, "Wider stance reduces body sway and motion sickness," in *Proc. the First International Symposium on Visually Induced Motion Sickness, Fatigue, and Photosensitive Epileptic Seizures*, Hong Kong, 2007, pp.18-23.

[12] R. Yasui, I. Matsuda, and H. Kakeya, "Combining volumetric edge display and multiview display for expression of natural 3D images," in *Proc. SPIE 6055*, San Jose, 2006, pp. 0Y1-0Y9.

[13] H. Kakeya, "Moevision: Simple multiview display with clear floating image," in *Proc. SPIE 6490*, San Jose, 2007, pp. 64900J.1-64900J.8.

[14] T. Nishihira and H. H. Tahara, "Apparatus for recovering eyesight utilizing stereoscopic video and method for displaying stereoscopic video," U.S. Patent US7 404 639 B2, Jul 29, 2008.

[15] H. Takada, K. Fujikake, M. Omori, S. Hasegawa, T. Watanabe, and M. Miyao, "Reduction of body sway can be evaluated by sparse density during exposure to movies on Liquid Cristal Displays," *IFMBE Proceedings*, vol. 23, no. 3, pp. 987-991, 2009.

[16] H. Takada, K. Fujikake, T. Watanabe, S. Hasegawa, M. Omori, and M. Miyao, "A method for evaluating motion sickness induced by stereoscopic images on head-mounted display," in *Proc. SPIE 7237*, San Jose, 2009, pp. 72371P.1-72371P.8.

[17] H. Takada, T. Yamamoto, S. Sugiura, and M. Miyao, "Effect of an Eyesight Recovering Stereoscopic Movie System on Visual Acuity of middle-aged and Myopic Young People," *IFMBE Proceedings*, vol. 25, no. 11, pp. 331-334, 2009.

[18] A. Sugiura, M. Miyao, T. Yamamoto, and H. Takada, "Effect of strategic accommodation training by wide stereoscopic movie presentation on myopic young people of visual acuity and asthenopia," *Displays*, vol. 32, no. 4, pp. 219-224, 2011.

[19] M. Takada, M. Miyao, M. Satoh, K. Yoshikawa, Y. Matsuura, and H. Takada, "Effect of accommodation training on visual function of visual inspection workers and middle-aged people," *Journal of Sports Medicine and Doping Studies*, vol. 2, no. 3, 2012.

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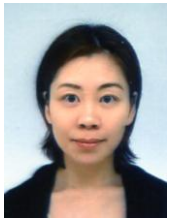

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