Comparison of Simultaneous Measurement of Lens Accommodation and Convergence in Viewing Natural and Stereoscopic Visual Target

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***Abstract*— Recent advances have been made in 3D technology. However, the influence of stereoscopic vision on human sight remains insufficiently understood. The public has come to understand that lens accommodation and convergence are mismatched during stereoscopic vision, and this is the main reason for visual fatigue caused while viewing 3D images. The aim in this study is to compare the fixation distance of accommodation and convergence in viewing real objects and 3D video clips. Real objects and 3D video clips perform the same movements; therefore, we measured accommodation and convergence in subjects who watched both. From the result of this experiment, we found that no discrepancy exists in viewing either 3D video clips or real objects. Therefore, we argue that the symptoms in viewing stereoscopic vision may not be due to the discrepancy between lens accommodation and convergence.**

Keywords-component: accommodation, convergence, simultaneous measurement, stereoscopic vision

I. INTRODUCTION

Recently stereoscopic images have been used in various ways. In spite of this increase in 3D products, and the many studies that have been done on stereoscopic vision, the influence of stereoscopic vision on human visual function remains insufficiently understood. When viewing stereoscopic images, people sometimes feel visual fatigue, 3D sickness, or other discomfort [1].

Investigations of the influence of stereoscopic vision on the human body are essential in order to ensure the safety of viewing virtual 3-dimensional objects People often report symptoms such as eye fatigue and 3D sickness when continuously viewing 3-dimensional images. However, such problems are unreported with so-called natural vision. One of the reasons often given for these symptoms is that lens accommodation and convergence are inconsistent during the viewing of 3D images [1, 2, 3].

Accommodation is a reaction that occurs due to the differences of refractive power by changing the curvature of the lens with the action of the *musculus ciliaris* of the eye along with the elasticity of the lens. The result is that the retina focuses on an image of the external world. Convergence is a movement where both eyes rotate internally, functioning to concentrate the eyes on one point to the front (Fig. 1).

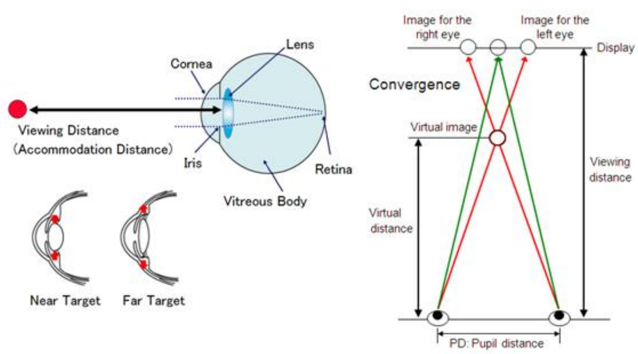

Figure 1. Lens accommodation and convergence

The relationship between accommodation and convergence is one factor that enables humans to see one object with both eyes. Convergence occurs when an image is captured differently with both eyes (parallax). At the same time, focusing on an object is achieved by accommodation. The main method of presenting 3-dimensional images is through the manipulation of the viewers mechanism of binocular vision, and many improvements have been made in this technology.

We suggest that a discrepancy between accommodation and convergence does not exist even when viewing in stereoscopic vision. Our previous study obtained results that indicate that the supposed inconsistency between accommodation and convergence does not occur [4]. In this present study, we performed a more detailed investigation confirming the non-existance of this discrepancy. In section 2, we explained how to measure accommodation and convergence simultaneously, and we showed the result of our experiment in section 3. Then, we discussed our experiment in section 4. Finally, we stated our conclusion and future works in section 5.

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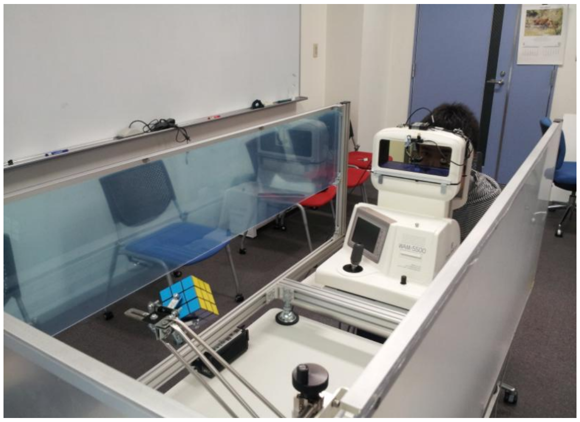

Figure 2. The scene of the measurement

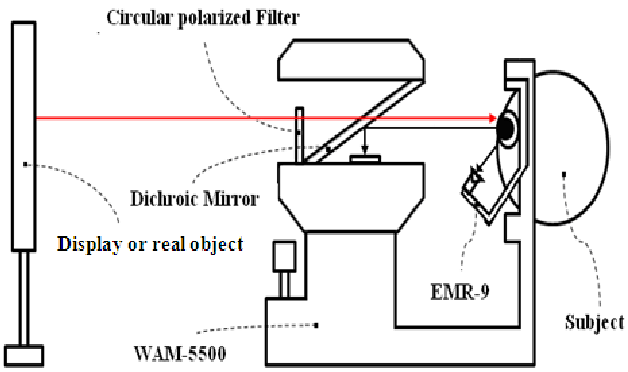

Figure 3. The overview of the measurement process

II. METHOD

We used an original machine developed by combining WAM-5500® and EMR-9® to perform the simultaneous measurements of accommodation and convergence. The experiment was conducted with the help of seven subjects (male and female)

Subjects gazed in binocular vision at a real object in natural vision (a Rubik's cube) and then at a virtual object of 3D video clips presented in front of them (Fig. 2). We measured their lens accommodation and convergence (Fig. 3). The objects viewed by the subjects in natural and stereoscopic vision showed exactly the same motion, and there were three kinds of movements of these objects (Fig. 4).

(1) The objects of natural and stereoscopic vision moved forward and backward at a range from 0.5 to 1m with a cycle of 10 seconds. It was repeated four cycles per single measurement.

(2) The second movement was the same motion as in movement one, but the time of a single cycle of movement was 2.5 seconds.

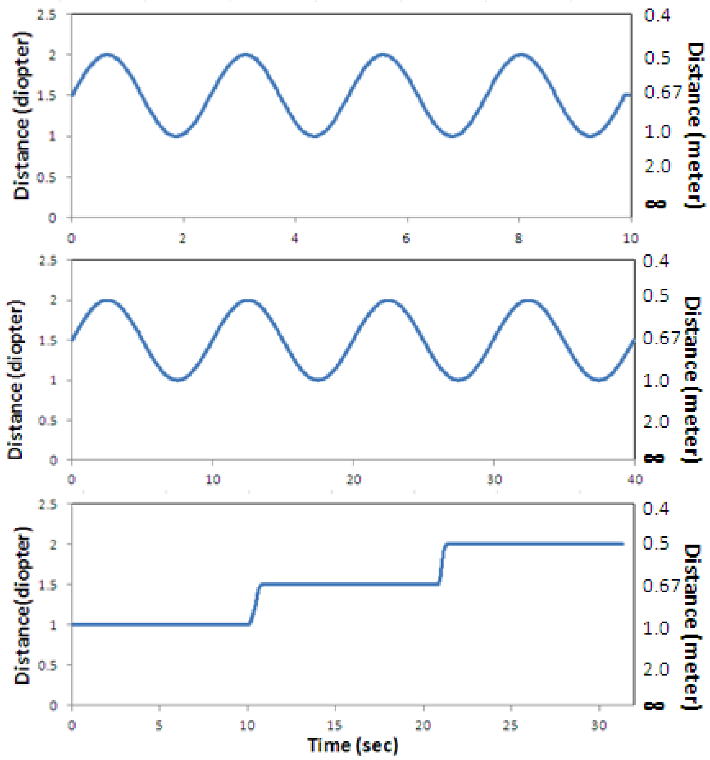

Figure 4. The movement of the object in natural and stereoscopic vision. (1) First was a cycle of 10 seconds. (2) Second was a cycle of 2.5 seconds. (3) Third was step motion, the object stopped at 1D, 1.5D, and 2D for each 10seconds.

(3) The object in this movement approached the subject. Initially, the position of the object was 1m from the subject. The object moved forward to the subject and stopped at the position of 1D, 1.5D, 2D for each 10 seconds (D represents diopter). A"diopter" is the refractive index of the eye lens, which is an index of accommodation power. It would be as follows 0D stands for infinity, 1D stands for 1 m, and 2D stands for 0.5m.

The measurements of the objects in both natural and stereoscopic vision were taken three times per one movement. The illuminance in this experiment was 103 lx.

III. RESULT

The measurements for all subjects showed roughly similar tendencies. Figs. 5 and 6 showed the results of movement 1, which were the moving objects in both natural and stereoscopic vision with a cycle of 10 seconds. The subjects in Fig. 5 and Fig. 6 were different.

Then, Figs. 7 and 8 showed the result of movement 2.

In all these figures, "accommodation" stands for the focal length of lens accommodation, while "convergence" stands for the convergent focal length, and "object" stands for the location of the real object in natural vision or the position of virtual image in stereoscopic vision.

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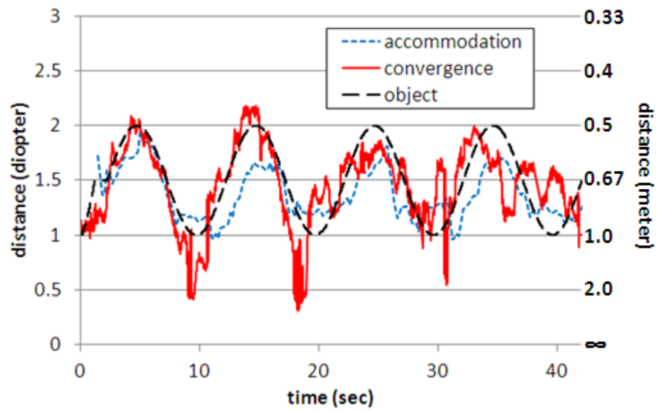

Figure 5. The result of natural vision (a cycle of 10 seconds)

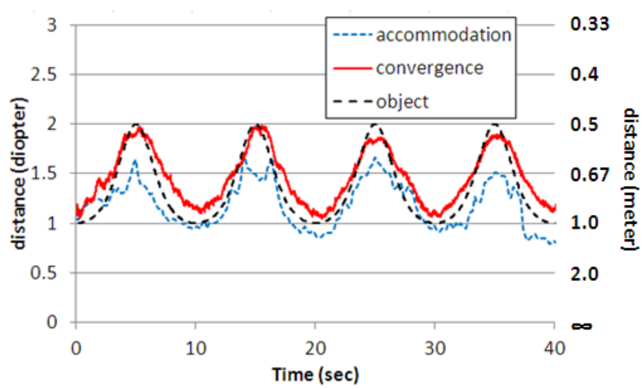

Figure 6. The result of stereoscopic vision (a cycle of 10 seconds)

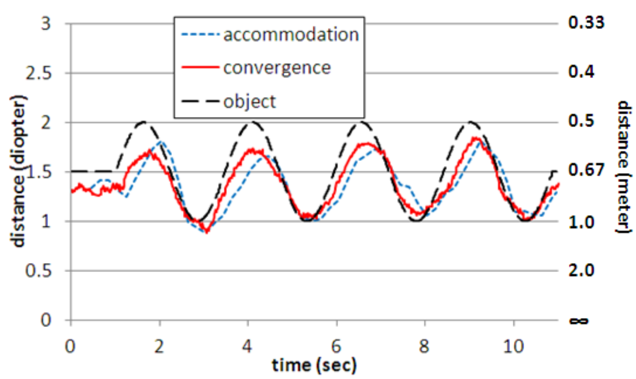

Figure 7. The result of natural vision (a cycle of 2.5 seconds)

All figures show that the accommodation and convergence of subjects changed in agreement. In Figs. 5 and 6, the change in the diopter value occurred within a cycle of about ten seconds and those in Figs. 7 and 8 did within a cycle of about 2.5 seconds. Moreover, the value nearly agreed with the distance from the subject to the position of the real object or virtual image. In the case of movement 3, lens accommodation and convergence also approximately agreed with the position of the virtual images.

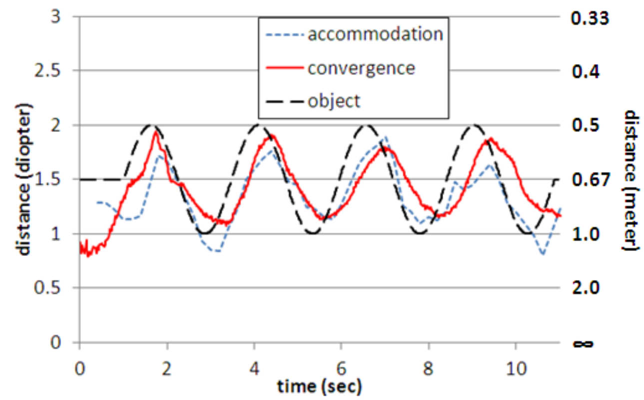

Figure 8. The result of stereoscopic vision (a cycle of 2.5 seconds)

IV. DISCUSSION

According to Hoffman [2] and Ukai & Howarth [3], lens accommodation in viewing 3D images would be fixed at the position of the display. However, or experiment found no mismatch in the accommodation-vergence.

In our previous study, we also reported the results of simultaneous measurement of lens accommodation and convergence while subjects viewed objects in stereoscopic vision, and the inconsistency between accommodation and convergence did not occur [5]. This study simultaneously measured accommodation and convergence in viewing 3D video clips of three movements, and the discrepancy was unconfirmed as in viewing real object. Therefore, we found that subjects watching 3D do not show any discrepancy between accommodation and convergence.

Subjects should be seeing blurred images if lens accommodation focuses on the virtual image position while a stereoscopic image project outwards. Subjects focusing on a nearer position rather than the display may be experiencing the condition in which humans look at a position beyond the farthest point of the object as in myopia.

Smith [6] showed that the relationship between the refractive error and visual acuity is linear. The visual acuity of subjects in Smith's experiment did not decrease much. Therefore, the distance from an emerging object in our experiment may not have been a problem and was correctly viewed by subjects.

Meanwhile, Patterson [7] reported that there should be a problem in only a near-eye display and that the accommodation-vergence mismatch likely would not occur under most stereoscopic display viewing conditions because of the depth of field.

Patterson [7] and Wang [8] also found that the depth of field was large, and they stated that the average total depth of focus was on the order of 1.0 diopter. Based on this value, the range of total depth of field would be from a distance of about 0.1m in front of a fixed point to about 0.17m behind the fixed point of 0.5m. For a fixed distance of 1m, the total depth of field would be from a distance of about 0.33m in

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front of the point to about 1.0m behind the point. For a fixed distance of 2 m, the total depth of field would be from about 1m in front of the point to an infinite distance behind the fixed point.

They also reported that the depth of field was affected in various ways by the pupil diameter and resolution.

Some researchers found that pupil diameter will be slightly over 6 mm for a luminance level of 0.03cd/m2 and near to 2 mm for a luminance level of 300cd/m2. For each millimeter of decrease in pupil size, the depth of field increases by about 0.12 diopters [7, 9].

Therefore, the value of accommodation can be in the range of the depth of field in our experiment.

In the future research, we plan further investigations concerning the influence of age, pupil diameter, the illuminance of the experimental environment, and the luminance of visual targets.

V. CONCLUSION

In this experiment, we simultaneously measured accommodation and convergence of subjects viewing real objects and 3D video clips. The video clips showed exactly the same motion as with the real objects. We did not confirm the existence of discrepancy between lens accommodation and convergence. Therefore, we believe it is inconclusive that symptoms such as eye fatigue and 3D sickness are caused by this discrepancy and be the result of other factors. We plan to perform further investigations including the change of pupil diameter in viewing stereoscopic vision, luminance level and the difference of the 3D presenting method in order to further comprehend the mechanism of stereoscopic vision.

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