Comparison of Simultaneous Measurement While Viewing Real Objects and 3D Video Clips

Tomoki Shiomi[1], Keita Uemoto[1], Takehito Kojima[1], Satoshi Hasegawa[2], Masako Omori[3], Hiromu Ishio[4], Hiroki Takada[5] and Masaru Miyao[1]
[1]*Nagoya Univ., Graduate Sch. of Inf. Sci., Chikusa-ku, Nagoya, Japan*
[2]*Nagoya Bunri Univ. Inazawa, Aichi, Japan*
[3]*Kobe Women's Univ., Suma-ku, Kobe, Japan*
[4]*Fukuyama City Univ., Fukuyama, Hiroshima, Japan*
[5]*Univ. of Fukui, Fukui, Japan*

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Abstract: The use of 3-dimensional images has been spreading rapidly in recent years such as in 3D films and 3D televisions. However, the influence of stereoscopic vision on human visual function remains insufficiently understood. The public has come to understand that lens accommodation and convergence are mismatched while viewing 3D video clips, and this is the main reason for the visual fatigue caused by 3D. 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. We measured accommodation and convergence in viewing real objects and 3D video clips. From the result of this experiment, we found that no discrepancy exists in viewing 3D video clips like real object. Therefore, we argue that the symptoms in viewing stereoscopic vision may not be due to the discrepancy between lens accommodation and convergence.

1 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. 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 (Fig.1) are inconsistent during the viewing of 3D images (Fig.2) (Lambooij, 2009).

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.

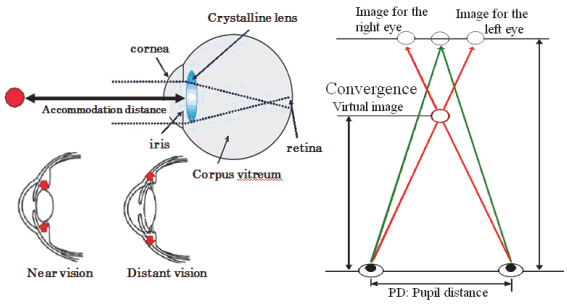

Figure 1: Lens accommodation and convergence.

Convergence is a movement where both eyes rotate internally, functioning to concentrate the eyes on one point in the front. The main method of presenting 3-dimensional images is through the use of the mechanism of this binocular vision.

We would like to argue that a discrepancy between accommodation and convergence does not

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exist, and we have already obtained results that indicate the inconsistency between accommodation and convergence does not occur in our previous study (Miyao, 1996). In this present study, we performed a more detailed investigations about nonexistance of this discrepancy.

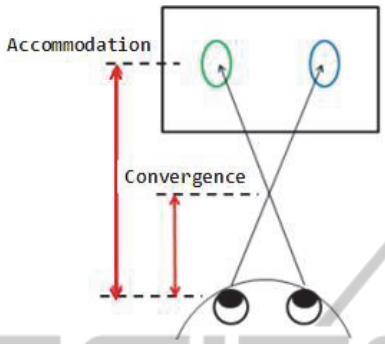

Figure 2: Discrepancy between accommodation and convergence.

2 METHOD

We used an original machine developed by combining WAM-5500® and EMR-9® to perform the simultaneous measurements of accommodation and convergence.

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. 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.

(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.

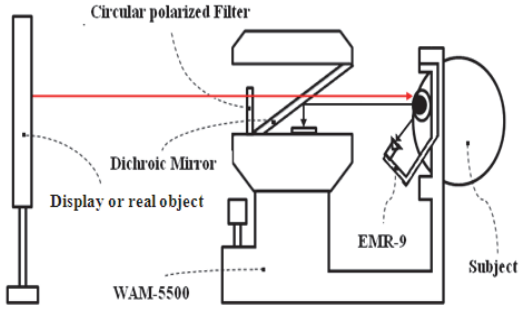

Figure 3: The overview of this experiment process.

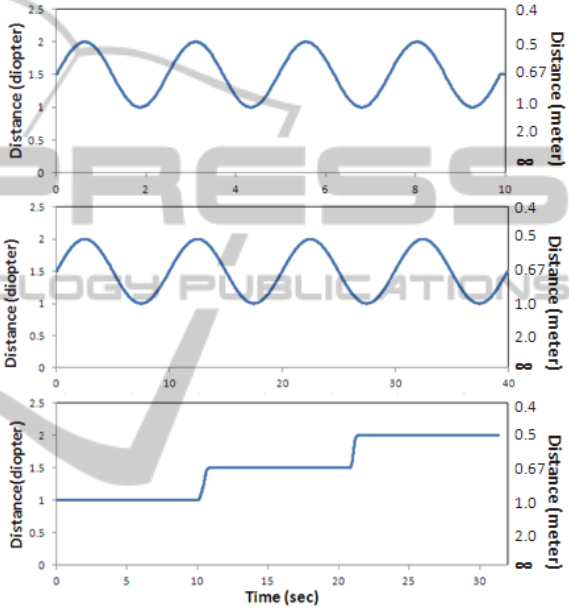

Figure 4: The movement of the object in natural and stereoscopic vision. (1) First was a cycle of 10 seconds. (2) Second was a cycle of 2.5 seconds. (3) Third was step motion, the object stopped at 1D, 1.5D, and 2D for each 10seconds.

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.

3 RESULT

The measurements for all subjects showed roughly similar tendencies. Figures 5-8 shows the results of movement 1 and 2, which is the moving object in both natural and stereoscopic vision with a cycle of 10 seconds or 2.5 seconds.

In all 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.

In Fig.5 and 6, these figures showed that the accommodation and convergence of subjects changed in agreement. The change in the diopter value occurred within a cycle of about ten seconds. The values of accommodation in both figures were 1.6D when object at the point of 2D and these values were 1D when object at the point of 1D. The value of convergence almost agreed with the position of the object.

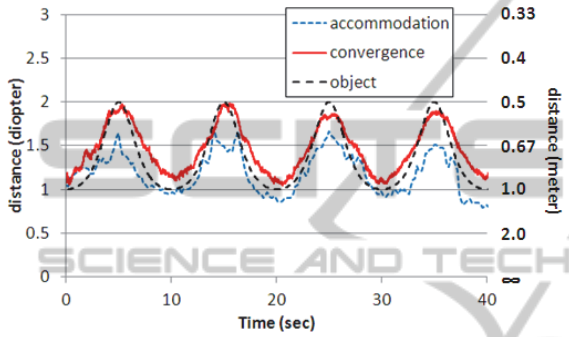

Figure 5: The result of natural vision (a cycle of 10 seconds).

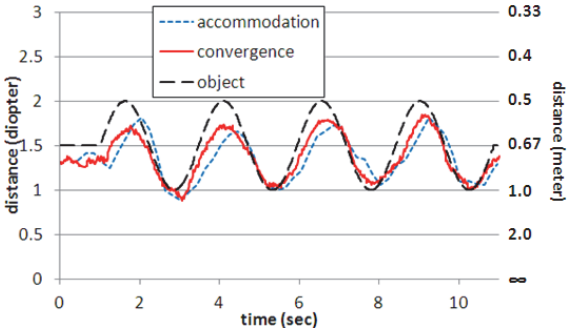

Figure 6: The result of stereoscopic vision (a cycle of 10 seconds).

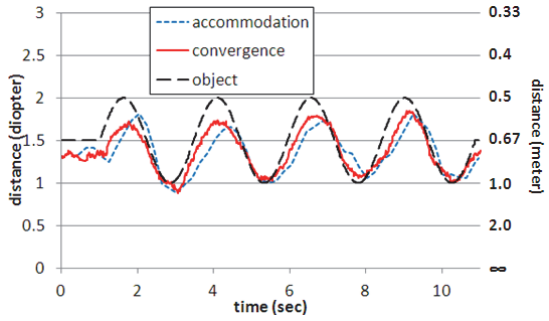

Figure 7: The result of natural vision (a cycle of 2.5 seconds).

In the case of movement 2 and 3, lens accommodation and convergence almost agreed with the position of the virtual images though the focal point of accommodation often shifted to the far point slightly.

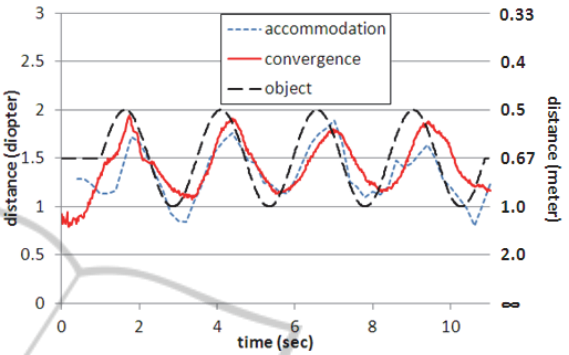

Figure 8: The result of stereoscopic vision (a cycle of 2.5 seconds).

4 DISCUSSION

According to Hoffman et al. and Ukai and Howarth (Ukai and Howarth, 2008), lens accommodation in viewing 3D images would be fixed at the position of the display. They have reported that an accommodation-vergence mismatch can create problems such as eyestrain and visual discomfort due to the synergy between accommodation and convergence. However, our experiment found no mismatch between accommodation and convergence. 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 (Hori et al., 2011). 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 so 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 showed that the relationship between the refractive error and visual acuity is linear (Smith,

1991). 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 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, 2009). Patterson (2009) and Wang and Ciuffreda (2006) 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 (Wang anda Ciuffreda, 2006). 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 1 m, the total depth of field would be from a distance of about 0.33m in front of the point to about 1.0 m 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 (Patterson, 2009).

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.

5 CONCLUSIONS

In this experiment, we simultaneously measured accommodation and convergence of subjects viewing real object and 3D video clips that showed exactly the same motion as in 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 not caused by this discrepancy but other factors. We plan to perform further investigations and studies of other variables.

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