Effects of Long-Time 3D Viewing on the Eye Function of Accommodation and Convergence

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Abstract. Recently we developed a device by combining a binocular autorefractometer and an eye mark recorder. Then, using the device together with images of very natural and high quality, we have carried out a sequence of experiments on simultaneous measurements of both accommodation and convergence while viewing virtual 3D objects.

The results show that there is essentially no discrepancy in the dynamical behaviors of accommodation and convergence especially for young subjects and that they are hence very close to the case of natural viewing of real 3D objects.

Following our previous experiments, we now investigate effects of long-time viewing of virtual 3D objects on the eye function of accommodation and convergence. We show that the synchronous dynamical behaviors of accommodation and convergence are definitely not a temporal effect but last for a long time.

Keywords: 3D, virtual image, accommodation, convergence, long-time viewing.

1 Introduction

In the history of human-computer interaction technology, our understanding of eye function in the context of 3D viewing has been developed. In the case of viewing real 3D objects, it is known that we use two mechanisms for binocular vision, i.e., accommodation and convergence. The former corresponds to lens focusing of each eye while the latter to rotational eye movement. Accommodation and convergence naturally cooperate, both concentrating on a target of our interest. On the other hand, the case of viewing virtual 3D objects was poorly understood.

It was long believed that convergence should follow the position of a virtual target popping in and out of a display while accommodation should always stay on the

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original images presented at the position of the display surface. Without any careful investigation, the disagreement in such fixation distances between accommodation and convergence was believed to cause eye fatigue when we watch virtual 3D pictures and movies [1].

Recently we developed a device by combining a binocular autorefractometer and an eye mark recorder. Then, using the device together with images of very natural and high quality, we have carried out a sequence of experiments on simultaneous measurements of both accommodation and convergence while viewing virtual 3D objects. The results show that there is essentially no discrepancy in the dynamical behaviors of accommodation and convergence especially for young subjects and that they are hence very close to the case of natural viewing of real 3D objects [2-6].

Following our previous experiments, we now investigate effects of long-time viewing of virtual 3D objects on the eye function of accommodation and convergence. One may say that the synchronous dynamical behaviors of accommodation and convergence which we found in our previous experiments might be temporal and would not last for a long time. In order to elucidate the fact, we use the same device and images as we developed previously and carry out extensive experiments for young subjects on long-time viewing of virtual 3D objects.

In the paper, we show that the synchronous dynamical behaviors of accommodation and convergence are definitely not a temporal effect but last for a long time. We also mention that the eye fatigue we often have when watching virtual 3D pictures and movies may not be attributed to discrepancy in the dynamical behaviors of accommodation and convergence but rather to poor quality of virtual images which are commonly used for now.

2 Method

We use a device originally developed for continuous and simultaneous measurement of both accommodation and convergence (Fig. 1). It is a combination of an autorefractometer (WAM-5500 produced by Grand Seiko Co., Ltd.) and a mobile eye mark recorder (EMR-9 produced by NAC Image Technology, Inc.). The former enables us to measure accommodation power with both eyes open and the latter to measure convergence distance, both allowing subjects to be unencumbered in their natural environment.

In the experiments, we set up a liquid crystal display (LCD) at the distance of 1m (1.0D) (Note: diopter (D) = 1/distance (m)) in front of subjects. The specification of the LCD is the following: MITSUBISHI RDT233WX-3D with a size of 23-inch and resolution of 1920 x 1080. A 3D movie is presented using a circular polarization filter system on the LCD screen. The images in the movie consist of a virtual metallic sphere superimposed in the blue sky with some clouds floating (Fig. 2). The sphere moves back and forth (i.e., harmonic oscillation) at the center of the screen with a period of 10 seconds. The pop-up range of the periodic motion is at a distance between 1m (1.0D) and 50cm (2.0D) from the subjects. Those images are of very

natural and high quality and were specially produced by using the technology called Advanced POWER 3D under the patent of Olympus Memory Works Corp.

Then in a dark room we carry out experiments to measure accommodation and convergence simultaneously while subjects are asked to continue to watch the spherical object in the 3D movie. The luminance of the spherical object was 113cd/m^2 at the center of the sphere and over the circular polarization filter. We obtained informed consent from all subjects and approval for the study from Ethical Review Board in the Graduate School of Information Science at Nagoya University.

Fig. 1. Device used for measurement of accommodation and convergence

Fig. 2. 3D images used for measurement of accommodation and convergence

3 Results

In Fig. 3, we present a result of relatively long-time (10 minutes) simultaneous measurement of accommodation and convergence in the case of a young subject (male at

age 21, wearing soft contact lenses for near sight vision correction) who continued to watch the 3D movie during the time. The figure shows synchronization of both accommodation and convergence which follow the position of the virtual object. Such an effect persists at least for 10 minutes. Here we find that accommodation never fixes to the position of the LCD screen at 1.0D.

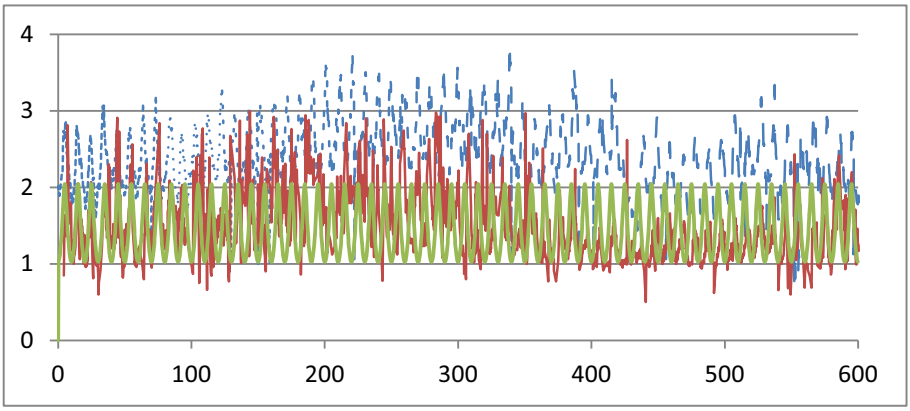

Fig. 3. Result of long-time measurement of accommodation (thin dotted line) and convergence (thin solid line) in the case of a young subject (male at age 21, wearing soft contact lenses for near sight vision correction). Thick regular oscillations confined between 1D and 2D refer to the theoretical position of the virtual spherical object at each time. Abscissa and ordinate indicate time in second and diopter (D), respectively.

4 Conclusions

As far as we use 3D images of very natural and high quality, accommodation especially for young subjects does not fix on the display surface but moves synchronously with convergence for a long time, following the position of virtual objects. Therefore, the binocular behavior in viewing virtual objects is found the same as in the case of viewing real objects.

In the case of middle-aged (over 40 years old) or elder subjects, weak hyperopia is or has already been developed. As a result, for such subjects, dynamical response of accommodation to virtual objects is expected very weak (but not completely vanishing) although they still try to have a clear view of the virtual objects with the help of changing pupil diameter [3,7,8]. For example, when an object approaches closer to the subjects, they unconsciously diminish their pupil diameter to gain the depth of field so that they can perceive the target without blurring [3,7].

In the experiment, we measured the behavior of accommodation and convergence for up to 10 minutes. However, measurement for longer-term viewing will be necessary if we apply the results to the case of watching 3D theater movies.

Finally, we mention that watching virtual 3D pictures or movies for a long time will often cause eyestrain, blurry vision, eye tiredness, headache and/or pain in or

around the eyes. According to investigations [9,10], subjects significantly suffer from such symptoms after 15 minutes sustained visual load. The researches so far discuss the relevance of those discomforts and convergence-accommodation conflicts in 3D vision [10,11]. However, we do consider that the discomforts should not be attributed to convergence-accommodation conflicts. It is because there is not such disagreement between accommodation and convergence especially for young subjects as we have seen in the paper. Instead, we conjecture that the main reason of having eyestrain would be attributed rather to poor quality of virtual images which are commonly used for now.

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