Evaluating the Legibility of Streoscopic Game Consoles

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Abstract. Recently, 3D technology has been developing and spreading into many aspects of our life; for example, in television and mobile phones. It is generally believed that during stereoscopic vision, a person' accommodation and convergence are mismatched when viewing 3D images and thus causing visual fatigue. During stereoscopic vision, while accommodation is fixed on the display showing a 3D image, convergence of the left and right eyes crosses at the location of the stereo-image. According to the findings presented in our previous observation, however, such explanations are mistaken. Results from our previous research found that accommodation is not fixed on the display and actually moved to suit convergence. We used a parallax barrier system for the 3D image in the previous study. In this experiment, we measured accommodation and convergence simultaneously using a handheld 3D game console (parallax barrier scheme).

Keywords: Accommodation, Convergence, 3D images.

1 Introduction

Recent advances in stereoscopic vision technology have brought us a wide range of display applications ranging from large TVs and public screens to small devices such as mobile phones and portable games. It is most probable that along with this trend, 3D representations not only of scenery images but of texts as well will become widely used on such devices in the near future.

The three-dimensional image display of two binocular views has become the mainstream in the present technology. The parallax (Fig.1) barrier system is also classified among them. The increase in 3D products has generated many studies on stereoscopic vision, but the influence of such a function on human sight still remains insufficiently understood [1, 2]. Investigations of the influence of stereoscopic vision on the human body are important in order to consider the safety of viewing virtual 3-dimensional objects. People often report symptoms such as eye fatigue and 3D sickness while 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 (Fig.2) and convergence (Fig.3) are inconsistently matched during the viewing of 3D images.

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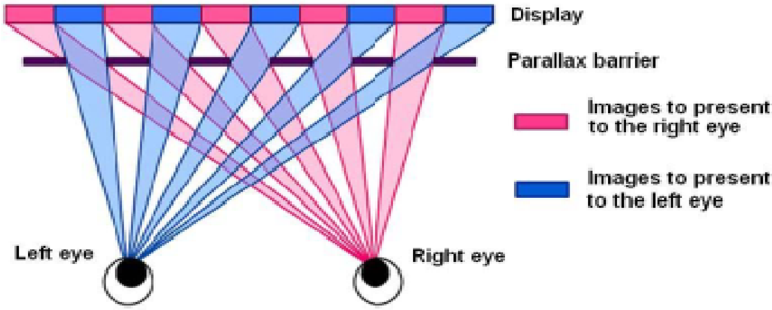

Fig. 1. Parallax barrier system

Accommodation is a reaction that occurs due to differences of the refractive power by the changing of 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 in the front. There is a relationship between accommodation and convergence 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 use of manipulating the mechanism of binocular vision, and many improvements have been made in this area of technology [3, 4]. Much of the literature contends that accommodation is always fixed on the screen where the image is displayed, while convergence intersects at the position of the stereo images. As a result, eye fatigue, 3D sickness, and other symptoms occur [5]. However, we obtained results that indicate inconsistency between accommodation and convergence does not occur [6]. Even so, today, inconsistency in viewing is still often given as a cause of eye fatigue.

In this study, we measured accommodation and convergence in subjects who watched 3D video clips while using handheld 3D game consoles.

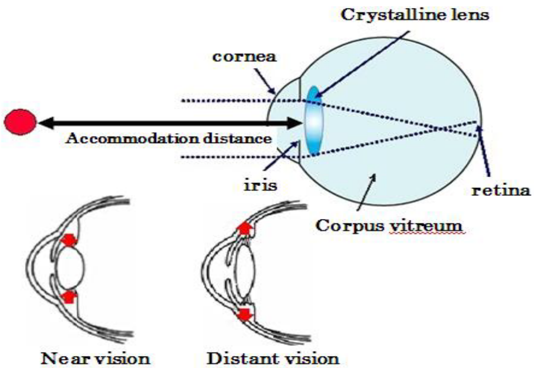

Fig. 2. Principle of lens accommodation

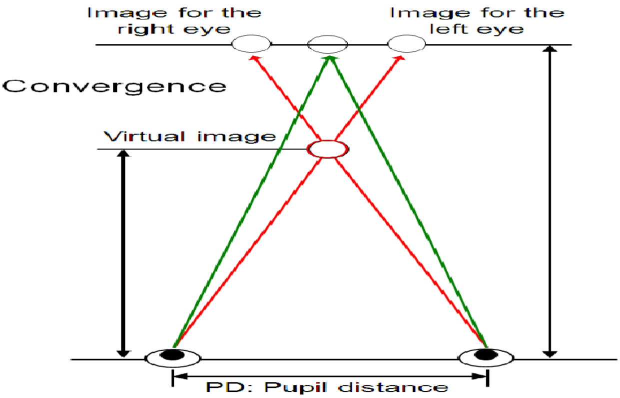

Fig. 3. Principle of convergence

2 Methods

Subjects were given a full explanation of the experiment in advance, and consent was obtained. The experiment was conducted with eight healthy people (age: 22 - 49). Subjects used their naked eyes or wore soft contact lenses, and their refraction was corrected to within ±0.25 diopter. ("Diopter" is the refractive index of the lens and is an index of accommodation power. It is the inverse of meters, for example, 0 stands for infinity, 0.5 stands for 2 m, 1 stands for 1 m, 1.5 stands for 0.67 m, 2 stands for 0.5 m, and 2.5 stands for 0.4 m). Devices used in this experiment were an auto ref/keratometer, WAM-5500 (Grand Seiko Co. Ltd., Hiroshima, Japan)(Fig.4) and an eye mark recorder, EMR-9 (NAC Image Technology Inc., Tokyo, Japan) (Fig.5).

Fig. 4. WAM-5500

Fig. 5. Eye mark recorder EMR-9

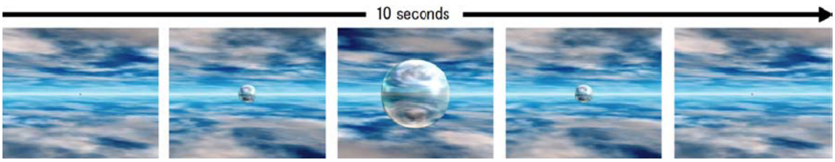

Fig. 6. Spherical Object Movies

Experiment. These WAM and EMR devices were combined, and we simultaneously measured focus distances of accommodation and convergence while subjects gazed at 3D video clip. The 3D video clips that we used in the experiment were trademarked as Advanced Power 3D® video clip (Olympus Memory Works, Corp.). The Advanced Power 3D is an image creation technique that combines near and far views in a virtual space and has multiple sets of virtual displays whose positions can be adjusted. The Advanced Power 3D is a natural video clip.

We placed the monitor of the handheld game console in front of the subjects at a distance of 40cm. We presented a 3D video clip on the monitor of the handheld game console (Fig.7). In the image, a spherical 3D object (Fig.6) moved forward and backward at a cycle of 10 seconds. The spherical object appeared as a 3D video clip located at a virtual distance of 40cm (i.e., the location of the LCD monitor) and moved toward the subjects to a virtual distance of 10 cm in front of them. We asked the subjects to gaze at the center of the spherical object for 40s and measured their lens accommodation and convergence distance during this period.

The illuminance of the experimental environment was about 122 (lx), and the brightness of the display of was 29.3 (cd/m^2) through a dichroic mirror.

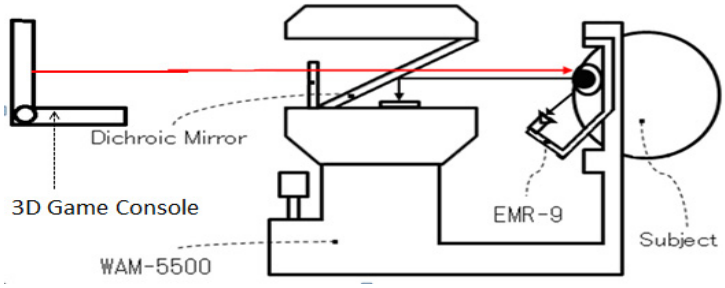

Fig. 7. Pattern diagram of measurements

3 Results

In this study, we simultaneously measured the subjects' accommodation and convergence while they gazed at a 3D object in binocular vision.

Figure 8 shows the pupil diameter of subject A (male, age 23). The changes of "accommodation" and "convergence" of subject A shown in Figure 9. The change of accommodation and convergence in the respective diopter values were nearly the same amplitude and were in phase as can be seen in same graph. These values fluctua ated synchronously with a cycle of 10 s, which corresponded with the cycle of the movement of the virtual 3D object. These figures show that the accommodation and convergence of subject A followed the position of the virtual 3D objects and were sync. Moreover, the change in the diopter value occurred with a cycle of about ten seconds. Not observed is related to convergence and pupil diameter.

Figure 10 shows the pupil diameter of subject B (male, age 49). The changes in "accommodation" and "convergence" of subject B are shown in Figure 11. The change of convergence in the respective diopter values were nearly the same amplitude and were in phase, as can be seen in same graph. these values fluctuated

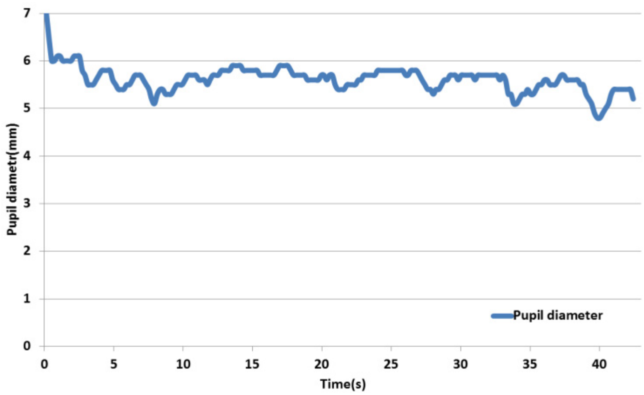

Fig. 8. The pupil diameter of subject A

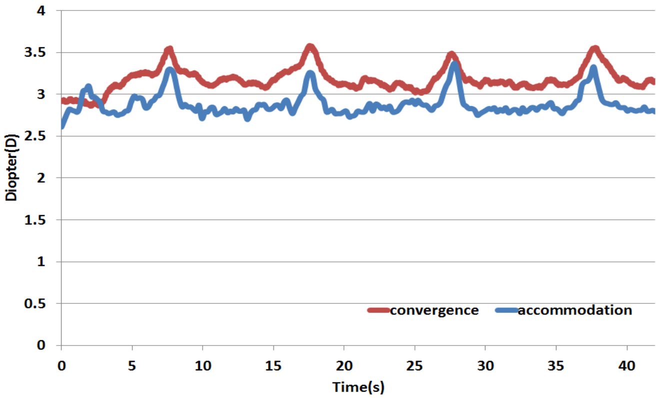

Fig. 9. The accommodation and convergence of subject A

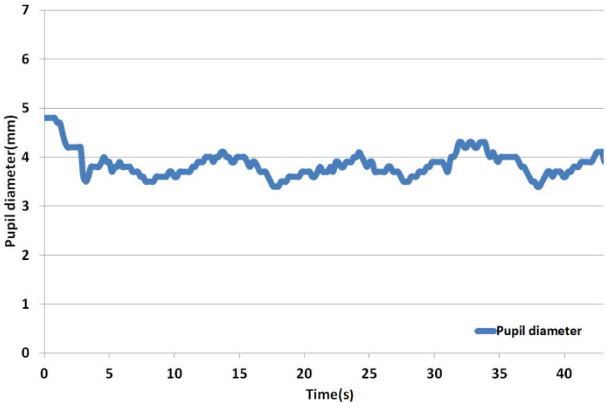

Fig. 10. The pupil diameter of subject B

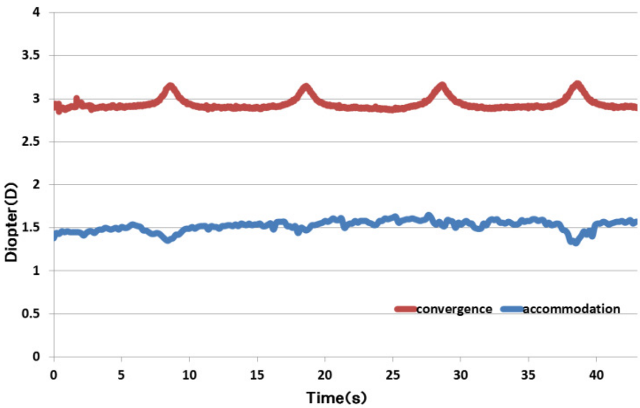

Fig. 11. The pupil diameter of subject B

synchronously with a cycle of 10s, which corresponded with the cycle of the movement of the virtual 3D object. Pupil diameter also changed according to the convergence. On the other hand, the change of accommodation was small.

4 Discussion

In this experiment, we used the WAM-5500 and the EMR-9 to measure the accommodation and convergence of subjects as they watched 3D objects on handheld game consoles. Our results show that accommodation and convergence in the younger subjects changed at a position between the nearest and furthest points as they gazed at a 3D object. Moreover, these changes occurred at a constant cycle, tuned to the movement of the virtual 3D object.

Therefore, accommodation and convergence among young people changed and synchronously followed the position of virtual 3D objects. On the other hand, the change of accommodation for the middle-aged subject's was small. This small change is due to the fact that accommodation ability decreases in middle-aged, which in turn is compensated for by changes in pupil diameter.

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