Lens Accommodation to the Stereoscopic Vision on HMD

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Abstract. The purpose of this study was to clarify the effect on visual function of gazing at stereoscopic images on a head mounted display (HMD). We measured visual accommodation during stereoscopic viewing while using a HMD by using our original instrument of measurement. The presented image was shown 3-dimensionally on an HMD set up at a visual distance of 3 cm. A spherical object moved back and forth toward and away from the observer in a 10 sec cycle. While the subjects were gazing at the 3D image with both eyes, the lens accommodation in the right eye was measured and recorded. Accommodation to the virtual objects was shown during the viewing of stereoscopic images of 3D computer graphics, but was not shown when the images were displayed without appropriate binocular parallax. It is suggested that stereoscopic moving images on HMD induced the visual accommodation by the expansion and contraction of the ciliary muscle, which is synchronizing with convergence.

Keywords: Binocular HMD, Stereoscopic image, 3-dimension, Visual function.

1 Introduction

Head mounted displays (HMDs) are now widely used in the world for viewing stereoscopic images. However, visual functions during stereoscopic vision on HMDs have been little studied. Lens accommodation with stereoscopic HMDs has not been measured, because the eyes are very close to the HMDs. To investigate the effects of stereoscopic images seen on HMDs on human vision, the authors measured lens accommodation in subjects as they watched stereoscopic images on an HMD.

Lens accommodation was measured for 40 sec as subjects gazed at 3D images on HMDs. Measurements were made when subjects gazed at 3D, Pseudo 3D, and 2D moving images with natural binocular vision.

We conducted the experiment using an HMD (Vuzix Corp; iWear AV920, 640 x 480 dot; Fig. 1) and Power 3D software (Olympus Visual Communications Corp).

Virtual images were created in the brain as shown in Fig. 2. The image was a sphere displayed stereoscopically on an HMD set at a visual distance of 3 cm.

To our knowledge there have been no reports on accommodation with stereoscopic HMDs. In this study we conducted an experiment on lens accommodation in response to 3D images on an HMD.

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Fig. 1. An HMD (iWear AV920, Vuzix Corporation; 640×480dot) used in the present experiment

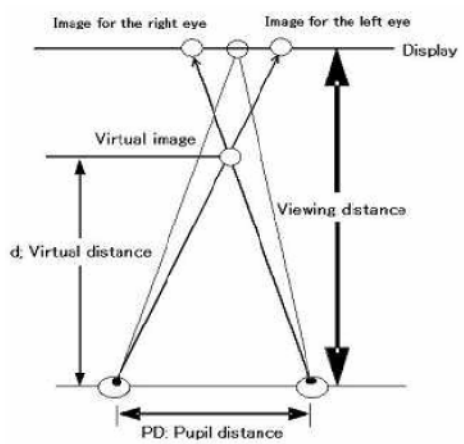

Fig. 2. Virtual image using convergence

2 Apparatus to Measure Lens Accommodation

A modified version of an original apparatus [1] to measure lens accommodation was used in the experiments. Accommodation was measured for 40 seconds under natural viewing conditions with binocular vision while a 3D image moved virtually toward and away from the subject on an HMD. For the accommodation measurements, the visual distance from the HMD to the subjects' eyes was 3 cm. The refractive index of the right lens was measured with an accommodo-refractometer (Nidek AR-1100) when the subjects gazed at the presented image via a small mirror with both eyes. The HMD was positioned so that it appeared in the upper portion of a dichroic mirror placed in front of the subject's eyes (Fig. 3). The 3D image was observed through the mirror. The stereoscopic image displayed in the HMD could be observed with natural binocular vision through reflection in the dichroic mirror, and refraction could be measured at the same time by transmitting infrared rays.

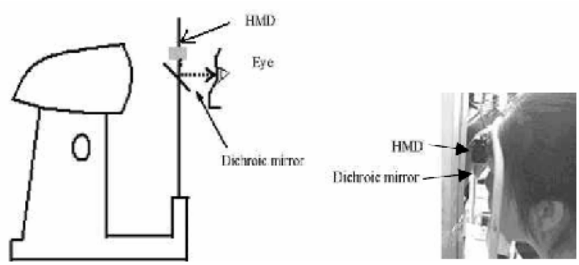

Fig. 3. Lens accommodation measured with a 3D content generation method on an HMD. An accommodo-refractometer (Nidek AR-1100) was used when the subjects gazed at the presented image via a small mirror with both eyes.

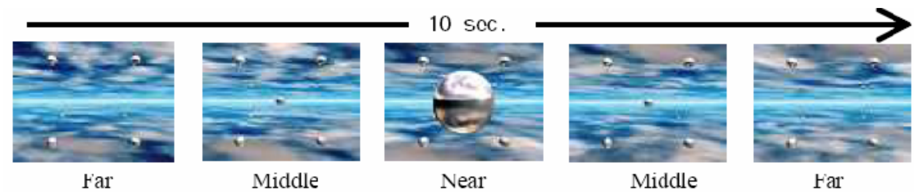

Fig. 4. Stereoscopic target movement

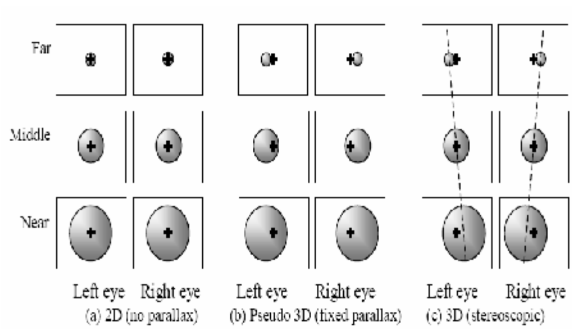

Fig. 5. Three parallax modes used in this experiment

The image was a sphere displayed stereoscopically on an HMD set at a visual distance of 3 cm. The sphere moved virtually in a reciprocating motion toward and away from the observer with the cycle of 10 seconds (Fig. 4).

The subjects were instructed to gaze at the center of the sphere, and the gaze time was set at 40 seconds. All subjects viewed tree types of images of 2D, pseudo 3D and 3D as shown in Fig.5. While both eyes were gazing at the stereoscopic image, the lens accommodation of the right eye was measured and recorded.

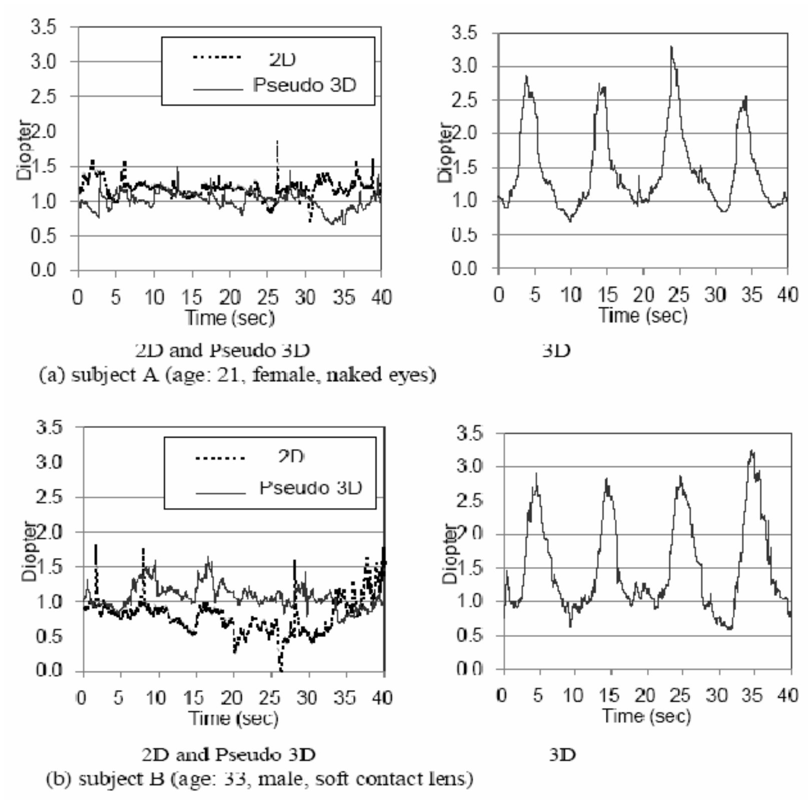

Fig. 6. Effect of different image content on lens accommodation. 2D, Pseudo 3D and 3D were shown in Fig. 5.

3 Results

The presented image was a 3-dimensionally displayed sphere that moved in a reciprocating motion toward and away from the observer with the cycle of 10 sec. (Fig.4). The subjects gazed at the sphere for 40 seconds. The results for 2D, pseudo 3D and 3D (Fig. 5.) are shown in Fig. 6.

Fig.6 (a) is a result of subject A (age: 21, female, naked eyes), and (b) is of subject B (age: 33, male, soft contact lens).

The results showed that large amplitude of accommodation synchronizing with convergence are shown only in 3D mode.

Accommodation occurred together with the movement of the stereoscopic image in 3D mode on the HMD (Fig. 6), and the lens accommodated so that the near point focus corresponded to the time when the visual target reached the nearest point virtually. It was shown that the focus then moved to a distant point as the virtual movement of the visual target was away from the subject. The amplitude of accommodation became smaller both in 2D and pseudo 3D.

Accommodation to the virtual objects was shown during the viewing of stereoscopic images of 3D computer graphics, but was not shown when the images were displayed without appropriate binocular parallax. It is suggested that stereoscopic moving images on HMD induced the visual accommodation by the expansion and contraction of the ciliary muscle, which is synchronizing with convergence.

4 Discussion

Lens accommodation was measured for 40 sec with subjects gazing at a 3D image under conditions of binocular vision using the HMD.

When the sphere moved closer, accommodation was made to approximately 3 Diopter in front of the eyes in the subject with the largest amplitude of accommodation. Immediately before the sphere reached the most distant point, the accommodation was about 1 Diopter. This demonstrates objectively that the ciliary muscle and ciliary zonule tense during near vision and relax during far vision, even when that vision is with virtual movement of a 3D image on an HMD.

Patterson and Martin [3] reviewed stereopsis and pointed out that perceived depth for crossed disparity follows predictions derived from constancy in most cases, whereas for uncrossed disparity perceived depth is frequently less than predicted. They reported that among several possible distance cues relating to the computation of perceived depth, one set of cues involves proprioceptive information from accommodation, convergence, or both.

To date there have been no reports on accommodation for stereoscopic HMDs. The present report showed the lens accommodation in response to 3D images on a HMD. There is empirical evidence that prolonged use of HMDs sometimes gives a feeling similar to motion sickness. The sensory conflict theory explains that motion sickness can occur when there are conflicting signals from the vestibular and visual systems [4]. In congruence with this theory, motion sickness can be induced without actual motion. Virtual reality systems are designed to be life-like [5], and the potential for visually induced motion sickness in virtual reality systems has been recognized [6]. Therefore, we are planning another experiment on the effects of stereoscopic views on HMDs on motion sickness, using stabilograms.

5 Conclusion

We investigated lens accommodation in stereoscopic vision on HMDs. Actual accommodation for stereoscopic views on HMDs was confirmed. Since HMDs are promising devices for ubiquitous virtual reality, further research, including that on 3D image sickness, is merited.

Acknowledgement

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