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Evaluating user experience of 180 and 360 degree images

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Abstract

This paper describes a comparison of user experience of virtual reality (VR) image format. The authors prepared the following four conditions and evaluated the user experience during viewing VR images with a headset by measuring subjective and objective indices; Condition 1: monoscopic 180-degree image, Condition 2: stereoscopic 180-degree image, Condition 3: monoscopic 360-degree image, Condition 4: stereoscopic 360-degree image.

From the results of the subjective indices (reality, presence, and depth sensation), condition 4 was evaluated highest, and conditions 2 and 3 were evaluated to the same extent. In addition, from the results of the objective indices (eye and head tracking), a tendency to suppress head movement was found in 180-degree images.

1. Introduction

In recent years, with the popularization and development of VR headsets, various VR contents have been produced. In particular, a 360-degree image can be viewed regardless of the type and performance of the headset. In addition, with the advent of inexpensive 360-degree cameras, users can easily shoot and share 360-degree images.

However, problems have been pointed out as the use cases of 360-degree image widespread. For example, there are restrictions on the shooting method, and it is difficult to shoot in stereoscopic (3D). On the other hand, by setting the viewing angle to 180-degree, 3D / 180-degree image has been proposed as a format that achieves both 3D and wide viewing angles [1]. Currently, several 3D /180-degree cameras are on the market, but it is still unclear what characteristics are in the user experience.

Concerning VR images, many studies are particularly considering the effects of devices. Fonseca et al. investigated the effects of viewing 360-degree videos with head-mounted and hand-held displays on attitudes and behaviors [2]. The results showed that immersive feeling and emotional increase presence and affect behaviors. Tse et al. studied the impact of a headphone and a headset on 360-degree video viewing [3]. The results showed that a headphone increased the immersive feeling when using a headset while decreasing the immersive feeling when using a smartphone. It was also suggested that using a headset increases presence but does not necessarily cause empathy or interest. Passmore et al. examined the user experience when viewing 360-degree images using a headset, smartphone, and flat display [4]. As a result, it was found that the headset has a higher presence and immersion, but the concentration and comfort in the story are higher on the display.

2. Purpose

The authors have studied physiological and psychological effects by observing 360-degree images using a headset [5]. From the results, some characteristic observation behaviors were observed, and the features of the stimuli were considered to be affected. The purpose of this research is to evaluate the user experience between viewing VR images in 180-degree or 360-degree environments.

3. Method

3.1 Equipment

Tobii Pro VR Integration (HTC Vive with Tobii Eye Tracking retrofit hardware), which can measure a direction of gaze, was used. The swiveling chair was used, and the position was fixed. The stimuli presentation environment was created by Unity using Tobii Pro SDK.

3.2 Stimuli

A 360-degree camera (Insta 360 Pro) was used to create stimuli that took full circumference 3D images. The stimuli resolution was 3840 × 3840 pixels in equirectangular format. Four stimuli were prepared with different conditions of binocular disparity and viewing angle.

Condition 1: monoscopic 180-degree image
Condition 2: stereoscopic 180-degree image
Condition 3: monoscopic 360-degree image
Condition 4: stereoscopic 360-degree image

The 180-degree images were processed with black on the back half and with blurs on the border.

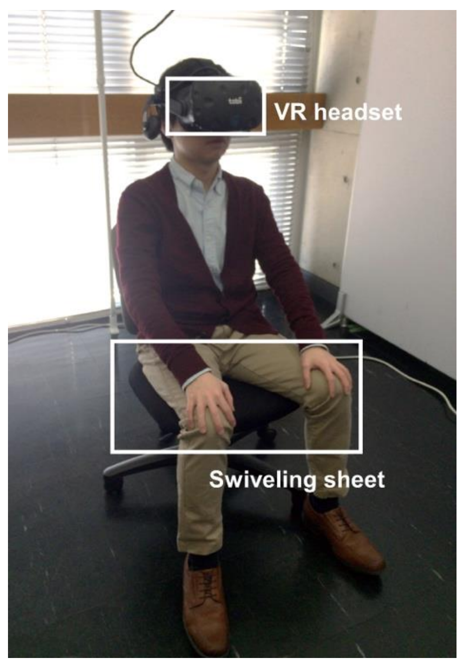

Figure 1. Experiment Layout

Figure 2. Stimuli in 360-degree image

Figure 3. Stimuli in 180-degree image

3.3 Evaluations

As a subjective index, the rating 7 scale was taken (Strongly disagree – Neutral – Strongly agree). The evaluation items were from the previous study on the evaluation of 3D images [6] – reality, presence, depth sensation.

As objective indices, gaze and head movement were measured with Tobii Pro VR Integration. The measurable field of view was 110 degrees which in full HTC Vive field of view, and the measurement frequency was 90 Hz.

3.4 Procedure

The participants were 16 college students with normal stereoscopic function. The purpose and method of the experiment were explained in advance, and their consent was gained. Participants were familiarized with the experimental procedure through preliminary trials. They watched the calibration marker, then they watched each image, each image was viewed for 40 seconds. The questionnaires were completed after viewing. The calibration showed a white cross in the center of the black background. Considering the possible influence of viewing order, the image presentation order was randomized.

4. Results

4.1 Subjective Index

A two-way ANOVA was carried out on the score of each subjective item. The result of each item is shown in the figures 4-6, and error bars are standard errors.

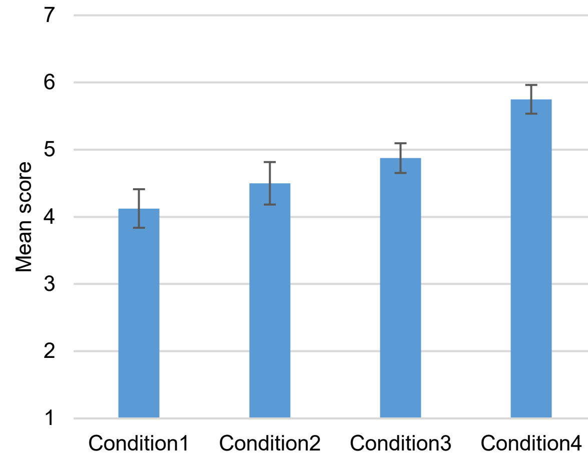

Figure 4. Result of Reality

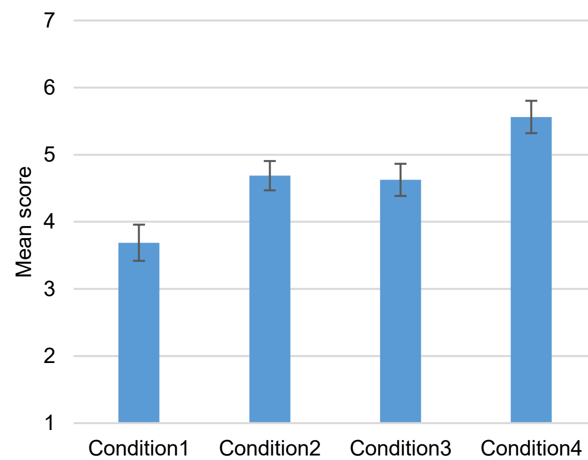

Figure 5. Result of Presence

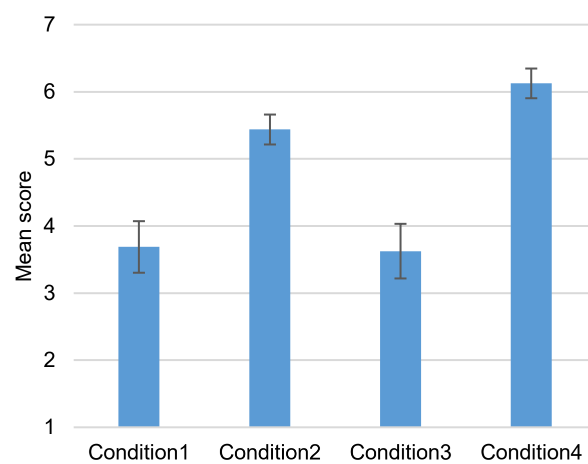

Figure 6. Result of Depth sensation

On reality, there were significant main effects of disparity and viewing angle and there was a tendency interaction effect (Disparity: $F(1, 15) = 10.14$, $p = .006$, $\eta 2 = .070$, Angle: $F(1, 15) = 25.26$, $p < .001$, $\eta 2 = .178$, Disparity × Angle: $F(1, 15) = 4.29$, $p = .056$, $\eta 2 = .011$). The disparity had an simple effect on 360-degree images ($F(1, 15) = 18.85$, $p < .001$, $\eta 2 = .212$). The viewing angle had an simple effect on monoscopic images ($F(1, 15) = 19.29$, $p < .001$, $\eta^2 = .125$), and stereoscopic images ($F(1, 15) = 19.74$, $p < .001$, $\eta^2 = .263$).

On presence, there were significant main effects of disparity and viewing angle (Disparity: $F(1, 15) = 19.50$, $p < .001$, $\eta^2 = .155$, Angle: $F(1, 15) = 22.01$, $p < .001$, $\eta^2 = .178$, Disparity × Angle: $F(1, 15) = .105$, $p = .751$, $\eta^2 < .001$).

On depth sensation, there was a significant main effect of disparity and there was a significant interaction effect (Disparity: $F(1, 15) = 21.57$, $p < .001$, $\eta^2 = .413$, Angle: $F(1, 15) = 2.14$, $p = .164$, $\eta^2 = .008$, Disparity × Angle: $F(1, 15) = 6.43$, $p = .023$, $\eta^2 = .013$). The disparity had an simple effect on 180-degree images ($F(1, 15) = 12.05$, $p = .003$, $\eta^2 = .341$), and 360-degree images ($F(1, 15) = 30.00$, $p < .001$, $\eta^2 = .493$). The viewing angle had an simple effect on stereoscopic images ($F(1, 15) = 7{,}35$, $p = .016$, $\eta^2 = .138$).

4.2 Objective Indices

The result of horizontal distribution by kernel density estimation of gaze and head tracking data is shown in the figures 7-8.

In the 180-degree images, in the vicinity of 0 degrees, the ratio of the head movement was large and the ratio of the gaze was small. On the other hand, in the vicinity of ± 90 degrees, the ratio of the gaze was large and the ratio of the head movement was small.

In the 360-degree images, there was no significant difference in the gaze and head movement distribution.

5. Discussion

As a subjective index, significant increases in reality and presence were observed from monoscopic to stereoscopic and from 180-degree to 360-degree images. It was also found that conditions 2 and 3 were evaluated similarly. From these results, disparity and viewing angles were considered to be evaluated similarly. Conditions 2 and 3 also caused the same level of reality and presence. Reality and depth sensation had significant interaction effects of disparity and viewing angle. We also found that Condition 4 was rated with the highest score. From these results, there was a synergistic effect of disparity and viewing angle.

As objective indices, there was a difference in the gaze and head distribution in 180-degree images. In addition, the gaze and head distribution were reversed around ± 50 degrees, and head movement was suppressed. This value is about half the viewing angle of the headset used, and it was considered that head movements were suppressed when the boundary line between the image and the black color was visually recognized. In the 360-degree images, the distribution of gaze and head near 0 degrees was large. From the author's previous research [5], this result was considered to be the effect of head orientation at the start of image presentation.

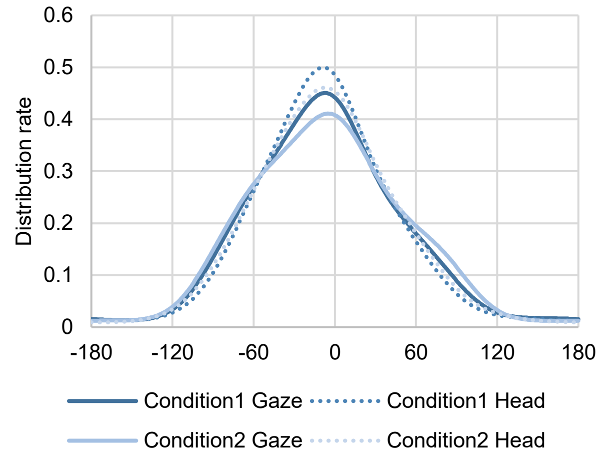

Figure 7. Result of distributions on 180-degree images

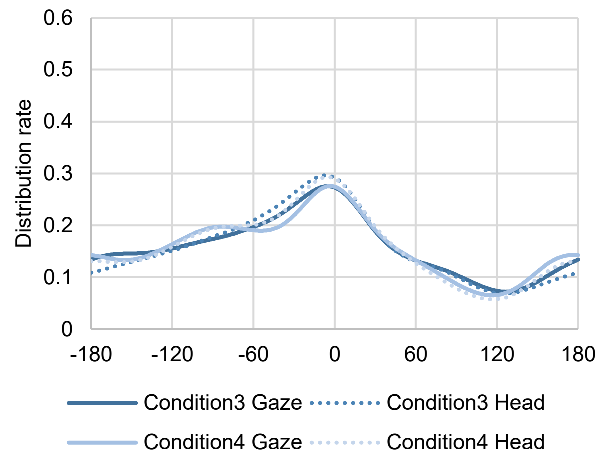

Figure 8. Result of distributions on 360-degree images

6. Conclusion

This research focused on the user experience of VR image formats. The experiment was conducted on monoscopic / stereoscopic and 180 / 360-degree images, and psycho-physiological indices were obtained. From the results, the following findings were obtained.

- The ratings of reality and presence were similar rating both monoscopic 180-degree and stereoscopic 360-degree images
- There was a synergistic effect of depth cues on user experience by stereoscopic 360-degree
- The boundary in 180-degree images might suppress head movements

These findings are regarded as a basic characteristic of user experience for VR content creation. In the future, the author will examine the viewing angle in between 180 and 360-degree.

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