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The Effects of Recording Distance and Viewing Distance on Presence, Perceptual Characteristics, and Negative Experiences in Stereoscopic 3D Video

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Abstract

The study explores the effects of recording and viewing distances in stereoscopic 3D on presence, perceptual characteristics, and negative experiences. Groups of 20 participants were randomly assigned to each of the three viewing distances, and all participants were exposed to five versions of the stereoscopic 3D music video that differs in recording distance. The results showed that first, viewers felt a higher experience of presence and had a better perception of objects positioned near the cameras. Second, viewers felt a greater perception of screen transmission as the viewing distance increased. Finally, viewers felt a greater negative experiences due to the joint effects of recording and viewing distance. As investigating the influence of stereoscopic 3D content and viewing environments on psychological factors, the study expects to provide a guideline of human factors in 3D.

Keywords : 3D viewing environment, 3D Human Factors, Fatigue, Presence

Ⅰ. Introduction

The popularity of stereoscopic 3D (hereafter S3D) has not lasted long since the stereoscopic movie Avatar recorded unprecedented success in 2009. Falling and rising S3D are closely associated with viewing experiences. For instance, people would enjoy watching S3D because it provides a more immersive experience by adding depth to a 2D screen, on the other hand, people would avoid watching S3D because unnatural artifacts of S3D such as intensive depth provide psychological disturbances.

It is important to examine viewing experiences of S3D, yet it is not simple to disentangle how factors of the S3D system (e.g., content, displays, and viewing environments) influence viewing experiences. The artifacts of S3D that affect viewing experiences can appear until the moment that viewers watch a S3D content. It is also notable that those factors of S3D system can affect viewing experiences in-

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dependently as well as dependently [1]. Therefore, it is required to investigate how systematically viewing experiences are changed when such parameters of the S3D system jointly work, but most of the studies have focused on investigating the separate effects of each factor on viewing experiences.

The current study intends to provide a holistic view of S3D viewing experiences by controlling the entire process of S3D system from the content production to the viewing environment. The study created a set of S3D music videos that have different recording distances and showed them people in different viewing distances. That is, the study explores how recording and viewing distances in S3D influence viewing experiences such as presence, perceptual characteristics, and negative experiences (i.e., fatigue and unnaturalness). In the next section, the study discusses previous studies with respect to the current research domain.

Ⅱ. Literature Review

1. S3D Viewing Environment

Viewing experience in S3D can be considerably affected by the viewing environment. Wearing 3D glasses causes a reduction of the luminance of the display [2], which leads viewers to perceive less vividness and color on the screen [3]. Furthermore, it has been found that viewing position affects visual fatigue [4] and causes perceptual distortion of the objects [5]. Chung found that different seat locations in cinema influence negative experiences while watching S3D [6]. Specifically, increased distance from the middle seat elevated visual fatigue [6], whereas manipulating horizontally arranged seat position did not influence fatigue [6] [7].

The relationship between viewing distance and experience is attributed to the change of disparity. Although a S3D image itself maintains constant parallax on a screen, the binocular disparity of the viewer is changed as the distance from the viewer to the display changes. If a viewer sits too close to the screen, the person will suffer from excessive screen parallax, which triggers serious the accommodation-vergence conflict. On the other hand, if a viewer was located far away from the screen, the viewer is less likely to feel the stereoscopic effect, which would lead to a less immersive experience.

In a natural environment, the amount of binocular disparity corresponding to the depth of a certain object is inversely proportional to the square of the observation distance. In a S3D display environment, however, a gap between the screen parallax generated by the inverse proportion to the square of the shooting distance and the binocular disparity of the human viewer depending on viewing distance inevitably occurs, which results in perceptual distortion of shape and depth [5].

2. Presence in S3D Research

The concept of presence has been widely used to evaluate the effects of immersive media. Presence is defined as a psychological state in which virtual environments and objects are perceived to be real in either sensory or nonsensory ways [8]. Given that the number of sensory outputs from media influence presence [9], theoretically speaking S3D should arouse a greater sense of presence than 2D. In fact, researchers have found that viewers experience a greater presence with S3D than 2D [10] [11].

Depth perception allows viewers to feel an enhanced experience that is somewhat close to the real world. It is not confirmative if different levels of depth induce dissimilar presence. Lee and Chung investigated how different depth levels influence presence [12]. They induced different depth levels by manipulating S3D convergent points and found that depth level influences presence [12]. Given that the depth level of S3D content can also be changed by recording and viewing distances, the study explores how these features influence presence.

Research Question (RQ) 1. What effects do recording distance and viewing distance have on viewers' experience of presence?

3. Perceptual Characteristics in S3D

Many studies concerning the objective perception of S3D imagery on displays have been done, including factors such as size, depth, and shape perception. However, these studies did not explain the subjective feelings experienced by viewers when perceiving S3D imagery. This subjective experience has been regarded as a critical factor for the evaluation of S3D imagery, and thus, perceptual characteristics were proposed after carrying out research to develop appropriate criteria [13] [14]. These characteristics include depth perception, screen transmission, shape perception, message transmission, and spatial extension [12].

Depth perception is concerned with the perception of depth and proximity. Screen transmission is related to vividness, resolution, and the perception of color on the screen. Shape perception refers to the ability of a user to perceive the edges of various objects, enabling them to distinguish one object from another. Message transmission indicates how clearly the theme of the S3D content has been transmitted to the viewers. Finally, spatial extension refers to the feeling of the three-dimensional effects. Given that the size, depth, and shape of S3D environments are affected by recording and viewing distance, the study explores how subjective feelings of objects (i.e., perceptual characteristics) are determined by those factors.

RQ 2. What effects do recording distance and viewing distance have on viewers' experience of perceptual characteristics?

4. Negative Experiences

Although S3D provides depth information that allows viewers to experience a similar sense of the real world, the mechanism of viewing S3D objects is different from that of the real world, and such differences often cause viewers to face negative experiences. A scholar suggested factors causing negative experiences: display, content, individual characteristics, and viewing environment [5].

Researchers have found that a S3D content having an excessive disparity severely deteriorates viewing experiences. Although sitting in a safety zone alleviates such negative experiences, visual discomfort can still occur even within the safety area [15]. Perceptual distortions such as puppet-theater effect also damage viewing experiences. One of the reasons that make perceptual distortions present is mistreatment in the process of S3D production. As such content and viewing environment factors can influence negative feelings. Therefore, the study explores those relationships.

RQ 3. What effects do recording distance and viewing distance have on viewers' negative experiences such as fatigue and unnaturalness?

Ⅲ. Method

1. Apparatus and Manipulation

Five versions of S3D music video, which were identical except for recording distance, were produced for the experiment. An unknown music band and their music were used to reduce the influence of extraneous variables (e.g., popularity, familiarity).

Two Cannon 7D digital cameras were used for shooting the videos, and a parallel stereo rig called CMT2000, made by MIRACUBE, was exploited to adjust the configuration of the cameras. The distance between the two cameras was fixed at 11.55cm on the rig. The 3DTV used in the experiment was a Samsung UN46C7000, which had a screen sizeof 46 inches (width: 102cm, length: 57.5cm).

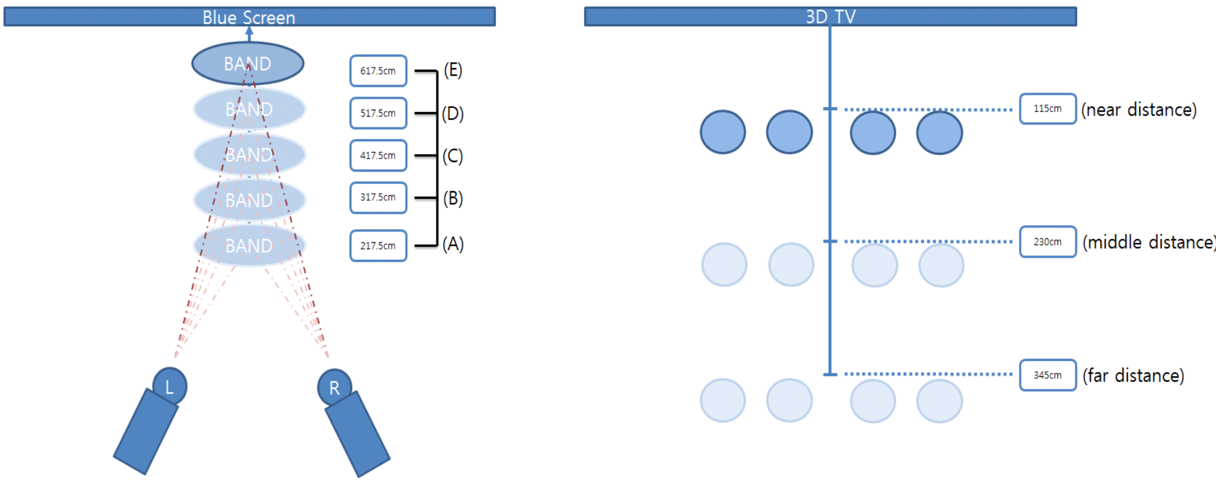

Fig. 1. Concept of Experimental Treatments. Left) Recording Distance of Experimental Treatments, Right) Viewing Distance in the Experiment

The five different distances between the object being shot and the cameras were 217.5cm (A), 317.5cm (B), 417.5cm (C), 517.5cm (D), and 617.5cm (E). Each of the respective convergent points was laid on the face of the performer located at the center of the stage. Manipulation of the viewing distance was aligned with the recommendations from the Korean government [16]. The range of the safety zone in this experiment was from 115cm to 345cm. To observe the effects of viewing distance, the safety zone was compartmentalized into three levels, each with a distance interval of 115 cm, thus resulting in the distances of 115cm (near), 230cm (medium distance), and 345cm (far). Figure 1 illustrates the concept of manipulation of the recording distance and viewing distance for the experiment.

2. Sample and Procedures

This study was carried out on 60 university students in Seoul, Korea, 33.7% of whom were male. The mean age of the participants was 21.6 (SD=1.95). A total of 16 of the participants (26.7%) indicated having watched an S3D video within six months of the experiment.

A mixed design was employed for the experiments. Groups of 20 participants were randomly assigned to each of the three viewing distances for the between-subjects design. Up to the maximum number of four participants was included in each session, and each session provided the treatments in a different order based on a Latin square design to compensate for the order effect. All participants were exposed to the five different versions of the S3D music video for the within-subject design. After watching each treatment, participants were asked to complete surveys about their experiences on the content.

3. Measures

The measurements adopted from previous studies [12] [13] were used with slight modifications. Presence was measured through four subscales, each referring to spatial involvement (e.g. I felt like I was in the stage), temporal involvement (e.g. I did not notice time passing while watching the video), dynamic immersion (e.g. I felt my body move to the right and left), and realistic immersion (e.g. I felt that the images in the video were realistic) [13]. Perceptual characteristic was measured through five subscales, each referring to depth perception (e.g. I could experience depth perception well), screen transmission (e.g.

Table 1. Reliability, Mean and Standard Deviation of Variables

Factor		Cronbach's Alpha	*Mean (M)*	*Standard Deviation (SD)*	Number of Questions
Presence	Spatial involvement	.91	2.59	.93	6
	Temporal involvement	.87	2.29	.90	4
	Dynamic immersion	.92	2.38	1.06	4
	Realistic immersion	.88	2.83	.98	3
Perceptual characteristics	Depth perception	.82	3.59	.66	6
	Screen transmission	.91	3.52	.94	3
	Shape perception	.75	3.26	.71	4
	Message transmission	.93	2.83	.98	3
	Spatial extension	.78	3.18	.88	3
Negative Experience	Fatigue	.90	2.80	.91	8
	Unnaturalness	.88	3.29	.90	3

The quality of the display was clear), message transmission (e.g., the subject of the content is clear) shape perception (e.g. I could easily distinguish the edges of objects) and spatial extension (e.g. It feels like the objects protrude from the screen) [12]. Negative experiences measured in two dimensions; fatigue (e.g. I felt visual fatigue) and unnaturalness (e.g. The video looks unnatural) [13]. All items were measured based on a 5-point Likert scale. The reliability, mean, and standard deviation of each variable are presented in Table 1.

4. A Mixed-design Analysis of Variance (ANOVA)

A mixed-design Analysis of Variance (ANOVA) with recording distance as the within-subjects factor and viewing distance as the between-subjects factor was carried out to test the three research questions. The effects of recording distance (within-subject factor) and the interaction effect between recording distance and viewing distance are reported using univariate test results. One of the assumptions that the univariate test requires in the repeated ANOVA is sphericity. The current study checked Mauchly's test in order to see if there is a violation of the assumption. If there is a violation, adjusted results by either Greenhouse-Geisser or Huynh-Feldt are recommended to report. It is suggested that when Greenhouse-Geisser epsilon is near or above .75, a result that is modified by Huynh-Feldt's adjustment is recommended to use [17]. Because all epsilons of Greenhouse-Geisser acquired in the current study are above .75, Huynh-Feldt's adjustment will be used when the assumption of sphericity is violated. Please refer to [18][19] for detailed information about a mixed-design ANOVA.

Ⅳ. Results

1. RQ1: Presence

RQ 1 concerns the effects of recording distance and viewing distance on presence. The overall results showed that participants felt a higher presence as the recording distance becomes shorter. In particular, amongst the subscales of presence spatial involvement was significantly associated with recording distance.

Mauchly's test showed that the assumption of sphericity was violated, ($x^2(9) = 45.79$, $p < .001$). A significant main effect of recording distance on presence was observed, $F(3.51, 199.85) = 2.91$, $p < .05$, partial $\eta^2 = .05$. The result of contrasts indicated there is a significant linear pattern, $F(1,57) = 9.51$, $p <.01$, partial $\eta^2 = .14$. The results of pairwise comparisons using Sidak showed that the viewers of treatment A (*Mean* (*M*) = 2.64, *Standard Error* (*SD*) = .10) reported higher levels of presence than the viewers of treatment E (*M* = 2.35, SD = .08, $p < .01$).

The subscales in presence were analyzed to gain more detailed information. Mauchly's test with spatial involvement also showed that the assumption of sphericity had been violated ($x^2(9) = 41.03$, $p < .001$). A significant main effect of recording distance on spatial involvement was observed, $F(3.37, 192.24) = 4.22$, $p < .01$, partial $\eta^2 = .07$. The result of contrasts showed there is a significant linear pattern, $F(1,57) = 12.67$, $p <.01$, partial $\eta^2 = .18$. The spatial involvement experience of viewers of treatment A (*M* = 2.81, *SD* = .13) was significantly higher than for treatment E (*M* = 2.37, *SD* = .11, $p < .01$).

2. RQ2: Perceptual Characteristics

RQ 2 concerns the effects of recording distance and viewing distance on the perceptual characteristics. The overall results indicated that participants tended to perceive higher perceptual characteristics of objects in S3D as the recording distance becomes shorter.

Mauchly's test showed that the assumption of sphericity was violated ($x^2(9) = 30.12$, $p < .001$), and the significant main effect of recording distance on the perceptual characteristics was observed, $F(3.54, 201.89) = 3.86$, $p < .01$, partial $\eta^2 = .06$. The result of contrasts indicated that there is a significant linear pattern, $F(1,57) = 8.75$, $p <.01$, partial $\eta^2 = .13$. The perceptual characteristics of viewers in treatment A (*M* = 3.47, *SD* = .07) and treatment E (*M* = 3.29, *SD* = .07) was marginally different, $p = .07$.

A set of subsequent analysis was also carried out on the subscales of perceptual characteristics to obtain more detailed results. Mauchly's test with depth perception showed that the assumption of sphericity was violated ($x^2(9) = 31.72$, $p < .001$). A significant main effect of recording distance on depth perception was obtained, $F(3.51, 199.85) = 2.91$, $p < .05$, partial $\eta^2 = .05$. The result of contrasts indicated that there is a significant linear pattern, $F(1,57) = 8.03$, $p <.01$, partial $\eta^2 = .12$. However, the depth perception of viewers in treatment A (*M* = 3.69, *SD* = .09) and treatment E (*M* = 3.48, *SD* = .08) was not significantly different, $p = .20$.

The sphericity of spatial extension was violated ($x^2(9) = 31.02$, $p < .001$), and there was a significant main effect of recording distance on spatial extension, $F(3.41, 194.23) = 6.71$, $p < .001$, partial $\eta^2 = .11$. The result of contrasts indicated there is a significant linear pattern, $F(1,57) = 10.76$, $p <.01$, partial $\eta^2 = .19$. Participants perceived higher spatial extension for treatment A (*M* = 3.46, *SD* = .12) than treatments D (*M* = 2.89, *SD* = .11, $p < .01$) and E (*M* = 3.00, *SD* = .12, $p < .05$). In addition, participants also felt more spatial extension with treatment B (*M* = 3.31, *SD* = .10) than with treatment D (*M* = 2.89, *SD* = .11, $p < .05$).

Viewing distance was found to have a main effect on screen transmission, $F(2, 57) = 3.97$, $p < .05$, partial $\eta^2 = .12$. Participants in the far viewing condition perceived higher screen transmission (*M* = 3.79, *SD* = .14) than that of those in the near condition (*M* = 3.23, SD = .14, $p < .05$).

3. RQ3: Negative Experiences

RQ 3 concerns the effects of recording distance and viewing distance on negative experiences. Mauchly's test indicated that the assumption of sphericity had been satisfied ($x^2(9) = 12.71$, $p = .18$). The interaction effects between recording and viewing distance was significant for negative experiences, $F(8, 228)= 2.46$, $p < .05$, partial η^2

= .08. A main effect of recording distance on negative experiences was significant $F(4, 228)= 4.58$, $p < .01$, partial $\eta^2 = .07$.

For fatigue, sphericity was assumed ($x^2(9) = 13.47$, $p = .14$), and the interaction effect was marginally significant, $F(8, 228) = 1.89$, $p = .06$, partial $\eta^2 = .06$. A main effect of recording distance on fatigue was significant $F(4, 228)= 4.23$, $p < .01$, partial $\eta^2 = .07$.

The assumption of sphericity for unnaturalness was also met ($x^2(9) = 10.07$, $p = .35$), and the interaction effect was significant, $F(8, 228) = 2.06$, $p < .05$, partial $\eta^2 = .07$. A significant correlation between fatigue and unnaturalness

Table 2. Results of Mixed-Design ANOVA

Factor			F values and effect sizes		
			Main effects		Interaction effects recording dis. × viewing dis.
			Recording distance	Viewing distance	
Presence		F	3.05*	.63	.73
			.05	.02	.03
Subscales of Presence	Spatial involvement	F	4.22**	.37	.66
			.07	.01	.02
	Temporal involvement	F	1.52	1.39	.73
			.03	.05	.03
	Dynamic immersion	F	2.12	.09	1.65
			.04	.01	.06
	Realistic immersion	F	1.34	.63	1.09
			.02	.02	.04
Perceptual characteristics		F	3.86**	1.64	1.49
			.06	.05	.05
Subscales of Perceptual characteristics	Depth perception	F	2.91*	.44	1.40
			.05	.02	.05
	Screen transmission	F	2.08	3.97*	.73
			.04	.12	.03
	Shape perception	F	1.47	.04	.81
			.03	.01	.03
	Message transmission	F	.14	1.47	1.07
			.01	.05	.04
	Spatial extension	F	6.71***	1.12	1.69
			.11	.04	.06
Negative Experiences		F	4.58**	2.13	2.46*
			.07	.07	.08
Subscales of Negative experiences	Fatigue	F	4.23**	1.80	1.89 (p=.06)
			.07	.06	.06
	Unnaturalness	F	1.92	1.90	2.06*
			.03	.06	.07

Note. *p < .05, **p < .01, ***p < .001, = partial was observed, $r(58)=.41$, $p < .01$. Table 2 details ANOVA results on presence, perceptual characteristics, and negative experiences.

Ⅴ. Discussion

1. Primary Findings

Based on the results, three conclusions are drawn: (a) viewers feel higher experience of presence and have better perceptions when the objects are positioned nearer to the cameras; (b) the perception of screen transmission is increased as the viewing distance becomes further from the screen; (c) negative experiences are emerged through the joint influence of recording and viewing distances.

First, concerning the main effect of recording distance, viewers experienced a higher feeling of presence and perceptual characteristics with treatment A than other treatment conditions. Given that the depth effect becomes greater when the distance between a camera and an object is close, greater depth perception might lead to more positive experiences. The results are consistent with a previous study reporting that people feel greater presence and better perception with negative parallax, which makes objects appear to be in front of the screen [12].

In addition, given that objects recorded in the nearer distance are shown to be larger and clearer than that of being placed in further distance, viewers were likely to perceive the environment better as well as to experience a more immersive feeling. It has been known that a large size of the image leads to a higher presence experience [9]. Although image size is changed along the viewing distance, the influence might not be enough to affect the feeling of presence and perceptual characteristics.

Interestingly, the results showing that recording distance significantly affects spatial involvement, depth perception, and spatial extension indicate that recording distance is closely related to spatial perceptions. Given that enabling a spatial sense is a unique function of S3D, producers need to consider recording distance in relation to the viewer's spatial experiences.

Second, screen transmission concerning the perceptions of vividness, resolution, and color on the screen, was affected by viewing distance. The participants sitting further from the 3DTV had a better perception of the screen transmission. In other words, increased viewing distance helps people perceive S3D images more clearly [4]. The results imply that sitting further from the display is encouraged when there is severe degradation of S3D quality possibly occurred due to post-processing for adjustment of the misaligned parameters such as parallax and color. Sitting further from the display will compensate for the annoying artifacts.

Finally, negative experiences emerged through the joint effect between recording and viewing distances. In general, increased viewing distance reduced the visual fatigue and discomfort because it decreased the binocular disparity. However, the main effect of viewing distance was not observed, rather the participants in the far viewing conditions seemed to feel higher negative experiences with treatment A than any other conditions. This unexpected result might attribute to perceptual distortion. As viewing distance increases, perceptual distortion of depth and shape of 3D objects increases. In the real world, the disparity is constantly changed by observer's distance, whereas the disparity of S3D is fixed on the screen level regardless of observer's distance, which leads to unnatural experiences [5]. The level of perceptual distortion becomes severe with large object images. Moreover, when an object is close to the cameras, the puppet-theater effect, which makes people perceive an unnaturally smaller image of an object than what the object really is, could occur [20]. Therefore, perceptual distortions occurring possibly due to the intertwined influence of recording and viewing distances might induce negative experiences.

2. Overall Implications and Future Research Directions

The implication of the study lies in the investigation of the joint effects of content features and viewing environments on the S3D viewing experience. Previous studies have limited to investigate those effects separately (e.g., [6][11][12]). However, as [1] argued, S3D systems such as content and viewing environments affect viewing experiences not only independently but also jointly. The results of the current study suggested that positive viewing experiences such as presence and perceptual characteristics are strongly associated with the content feature (i.e., recording distance), whereas negative viewing experiences are likely to be emerged by the joint influence of the content feature and the viewing environment (i.e., viewing distance). The results imply that future scholars can focus on content features when investigating positive viewing experiences, whereas they should adopt a more holistic evaluation approach when examining negative viewing experiences for S3D. Here, a holistic evaluation approach means taking the overall S3D systems into account. For instance, future research that aims to investigate the negative experiences of S3D will be required to investigate the joint effects of content, displays, viewing environments, and individual differences [1].

The interaction effects between recording and viewing distances on negative experiences call for future research studies to investigate the underlying mechanisms. Although this study explained the interaction effects based on perceptual distortions, it is still unclear how the combination of recording distance and viewing distance may cause perceptual distortions. We suggested that future studies investigate further on the subject to better understand the phenomenon.

The study produced content having different recording distance. We limited each content to have one unique level of the recording distances. However, given that a general S3D content includes dynamical scenes, it is likely to have various recording distances. It would be interesting to examine how dynamical changes in recording distance influence human factors.

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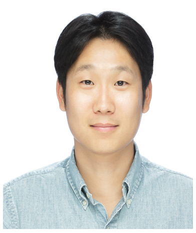

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