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Towards Safe Cities & Resilient Communities

13 & 14 SEPTEMBER 2018
IMPIANA HOTEL, IPOH, PERAK

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COMPARISON OF CHARACTERISTICS BETWEEN SCALE MODEL AND CG FOR THE EXPERIENCE BY SIMPLE VR HEADSET WITH THE SMARTPHONE

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Abstract - The purpose of this study is to use a scale model, which has long been popular in the expression of architecture, for the simple VR headset using the smartphone (S-VR) which is popular nowadays. While investigating spatial reproducibility of the simulation using S-VR, which is one of the important tasks of utilizing VR technology in architecture field, we clarified the characteristics of the spatial impression which is felt by the difference between the scale model (Mod) and CG expressing VR space. We considered not only the merit of those, but also the characteristics. First of all, we compared S-VR and Liquid Crystal Display (LCD). We conducted an experiment by the Semantic Differential scale method (SD method), and subjects evaluated seven levels by the 13 selected adjective-pairs. S-VR gained a higher evaluation on the spatial reproducibility than LCD. Therefore, we continued the investigation focusing on S-VR. Next, we compared the impression of the space due to the difference in expression medium used in S-VR, that is, CG and Mod, and clarify their characteristics using analysis of variance. Mod tends to be evaluated as "Open", "Like", "Friendly", while CG did as "Luxury" or "Oppressed". In CG, the difference in patterns of space gave different impressions. However, in Mod, it was less likely to influence the impression, that is, whichever pattern was similar impression. As a result, when comparing impressions by Mod, it is necessary to pay attention to those characteristics. In addition to characteristics clarified in this research, considering physical conditions and the time to create Mod, for simulation comparing multiple patterns, it is best to use CG as a space expression medium. While, for instance presentation, in the case of expecting to give a better impression to the space, it is effective to use Mod.

Keywords - VR, smartphone, scale model, SD method, spatial reproducibility

1 BACKGROUND AND PURPOSE

As a background social trend, there is development of VR technology. Inexpensive handy S-VR with smartphones can greatly contribute to the spread and penetration of VR technology into the world. However, it has been often discussed the characteristics and usefulness of each tool of VR, research on spatial reproducibility of S-VR with smartphones is still in the developing stage. The purpose of this study is to use a scale model, which has long been popular in the expression of architecture, for the S-VR which is popular nowadays.

Moreover, as a new problem of the VR technology in the architecture field, it is shown that their emotional factors may be different even though the experience equivalent to the real space can be experienced in the VR experience. In addition, from the viewpoint of emotional impression, considering the need to select various spatial representation methods depending on the purpose also when expressing the VR space, there is a possibility that it is necessary to verify using S-VR.

Based on these backgrounds, the objectives of this paper are the following two: To confirm the reproducibility of spatial simulation experiences using S-VR, and to clarify the characteristics of Mod and CG as a space expression method using S-VR.

2 LITERATURE REVIEW

2.1 VR Technology in the Architecture Field

VR technology is also used in the field of architecture. Originally we are using 3D CG technology to reproduce the space, so using the created data makes space simulation experience using VR technology relatively easy. One of the important tasks in VR technology in the architecture field is said to be spatial reproducibility [Tachi 2000]. Numerous attempts have been made to show to what extent the experience equivalent to real space is possible. Many studies were done to verify spatial reproducibility. Studies to examine features and usefulness based on differences in VR presentation devices [Ono 2004] and Reproduction of “brightness feeling” [Yoshizawa 2003] and others. However, the devices used for these are high-performance, high-performance and expensive in price. There are few verifications using devices that are inexpensive, such as VR technology using smartphones, and that are easy to operate without special knowledge. By verifying the spatial reproducibility with such a simple head mount display, there is a possibility that it will become a foothold for the spread of VR technology in the architecture field. However, it cannot be said that only the spatial reproducibility is a problem of the VR technology in the architecture field. It is suggested that even if experiences equivalent to real space are possible in spatial simulated experiences, the sensibility impression felt therefrom may be different. [Okura 2006], [Yokoi 2013] also studies psychological effects in the VR space.

2.2 Evaluation of spatial impression by difference in expression method

Various methods of expressing the space are also selected by improving the technology. It is said that it is better to use various methods according to purpose in order to express real space effectively, such as model, handwritten sketch, and CG parse [Oshida 2011]. However, it is common to use CG for representation of VR space. There is a method to shoot a model with 360 ° movie as another space representation method compatible with VR technology. However, as mentioned above, CG is often used in consideration of compatibility with VR technology, the time and labor required for manufacturing multiple patterns, and physical conditions such as the location of the production. The research of the above [Okura 2006], [Yokoi 2013] also uses CG only as an expression method. Nonetheless, in evaluating spatial impressions on the emotional side, even if VR technology is used, it will be necessary to grasp the characteristics of each CG and model and to select the spatial expression method according to purpose. However, in the case of using the VR technology, there are few studies that compare the spatial expression method from the emotional aspect and are studying the features and usefulness.

Today, when spatial simulation experiences with VR are used, it is common to use CG in view of physical conditions and convenience, but it cannot be said that it is necessarily valid. Therefore, in this research, we focused on the expression method of VR space in spatial simulation experience using S-VR.

"S-VR" in this research is regarded as a medium for making VR experiences with binocular lenses using stereoscopic viewing that can be easily used with smartphones. In addition, we compare the impression in the case of using the model for the VR spatial expression method and the case using the commonly used CG, not only the goodness but also the characteristics of both of them which is regarded as an expected index.

3 COMPARISON OF S-VR AND LCD – FIRST EXPERIMENT

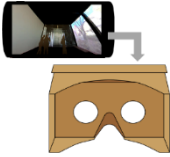

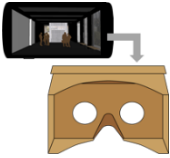

3.1 Outline of First Experiment

In order to confirm the difference in spatial impression and reproducibility in S-VR and LCD, by the 60th anniversary of Kyoto Institute of Technology in Japan, we conducted experiments for 30 people in their twenties. An image of a 1/10 scale model taken with a 360 degrees camera and a CG,

a total of 4 types of samples were prepared. Evaluation items were 13 emotional adjective pairs (7 levels of -3 to 3 / SD method). The outline of this experiment is shown below (Table 1).

Three patterns were prepared randomly in consideration of order effect. We did not establish a clear time limit for evaluation, and evaluated at the pace of the subject that the subject answered and asked the next question. We finished the experiment in 10 - 15 minutes. Also, the subjects were instructed to evaluate the impression of the space. The impression of the space and the impression of the device / expression method cannot be separated and mutually interfere, and the difference between the device and the expression method was read from the difference in impression for the same space.

Table 1 Outline of First Experiment

Purpose	Confirm the difference in spatial impression and reproducibility in S-VR and LCD		
Objects	Mainly for students, in their twenties (30 valid responses)		
Period	December 20, 2017 - December 30, 2017		
Contents	Look at the four samples and evaluate each impression with 13 adjective-pairs.		
Samples		S-VR	LCD
	Mod		
Samples		S-VR	LCD
	CG		
Procedure	0.	Explanation of experiment procedure	
	1.	Have the subject see 4 samples	
		I. Wear an S-VR and watch the images II. Watch LCD images	
	2.	Ask questions orally while watching each sample. Have them answer with numbers and the experimenter fills out the evaluation sheet	
3.	1-2 Repeat		

Several limitations exist in this study. Subjects are Japanese young people in their twenties and all have smartphones, so they are less resistant to VR technology. Therefore, you may be more interested in VR technology than true general population and may say that it is more reproducible for spatial reproducibility. This can be a selection bias. In this research we conducted verification by S-VR, which is a foothold of the spread of VR technology. However, because the mechanism is simple, it is limited to the space experience standing on the spot. The fact that the height of the line of sight is fixed and the walk-through function is not implemented, the reproducibility of the real space is limited.

3.2 Results of First Experiment

Mod and CG were summed up, and the evaluation items were simply tabulated for the device (Figure 1). Two groups of t-tests that corresponded between the devices were performed, and there was a significant difference at the 5% level in all the evaluation items. Correlation between S-VR and LCD was determined, and it was strong positive correlation with a correlation coefficient of 0.66. In addition, in all the evaluation items, the scale score difference obtained by subtracting the LCD from

the S-VR is positive, and there was a difference of two points or more in the items of "Reality / Not reality" or "Reproduced / Not reproduced". From this result, it was confirmed that S-VR was reproduced more than LCD.

Therefore, we stopped the experiment using LCD and continued the investigation focusing on S-VR. The comparison between Mod and CG will be dealt with in detail in the next section.

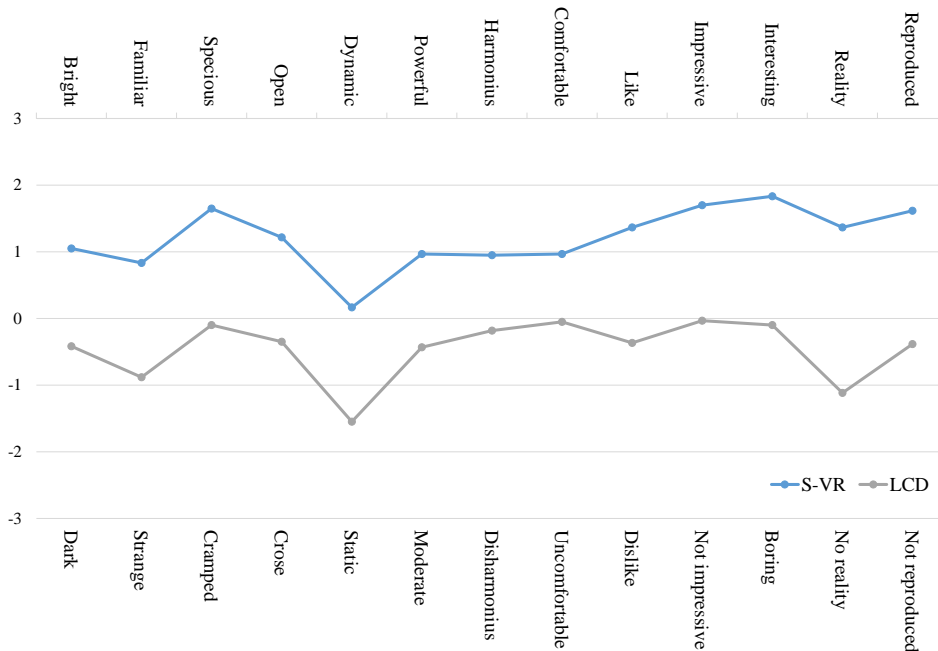


Figure 1 Scale scores of devices (n = 60).

4 COMPARISON OF MOD AND CG – SECOND EXPERIMENT

In recent years, as an effective method for decorating the overhead in a space with a high ceiling height such as an entrance, there are many cases where many ornaments of simple shape are suspended. In this study, we defined them as "hanging objects" and decided to evaluate the impression of the entire space including them. The difference in space was expressed by changing the pattern of objects hanging from the ceiling.

In the experiment, by the 60th anniversary of Kyoto Institute of Technology in Japan, we conducted experiments for 30 people in their twenties. We prepared images of 1/10 scale model taken by 360 degrees camera and CG. A total of 12 kinds of patterns of hanging objects were prepared with varying density and height -- 2 density patterns of hanging objects: 25 arranged 5 × 5 at equal and 49 arranged 7 × 7, at equal intervals in space of 1600 mm square, and 3 height patterns of hanging objects: "Flat" all the same height in the vertical direction, "Convex" the height decreases towards the center part, "Wave" the height changing in streamline form in both matrices. The height of the suspended object alone was set to be the height of 2700 mm from the ground at the highest position, and four kinds were prepared every 150 mm. The lowest position was set at a height of 2250 mm from the ground. The outline of this experiment is shown below (Table 2).

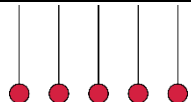
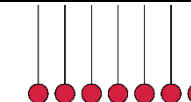
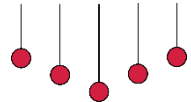
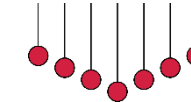
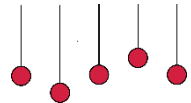
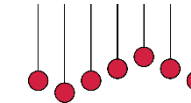
We did not establish a clear time limit for evaluation, and evaluated at the pace of the subject that the subject answered and asked the next question. We finished the experiment in 15 to 25 minutes. In consideration of the subject's burden, experiments were conducted with the mixing plan of patterns (6 types) × expression method (2 types).

In addition, from the previous experimental results, we used 16 adjective pairs selected and added with items suitable for spatial impression evaluation. Since strong positive correlation

(correlation coefficient is 0.64) was shown between items "Real / Not real" and "Reproduced / Not reproduced", only the item "Reality" was evaluated in this experiment.

In this study, we conducted an experiment using hanging group objects to construct the impression in the entrance space. We focused only on the density of the group in the horizontal direction and the change in height in the vertical direction, so it was an experiment limited to the group change on the plane. Because we did not deliberately deal with randomness, there is a possibility that the group change in different directions may be different factors of impression. In addition, since we performed experiments with limited elements such as the size, shape and color of the object itself, various studies are also required from that point of view.

Table 2 Outline of Second Experiment

Purpose	Clarify the characteristics of Mod and CG as a space expression method using S-VR		
Objects	Mainly for students, in their twenties (30 valid responses)		
Period	December 30, 2017 - January 20, 2018		
Contents	Look at the 12 samples and evaluate each impression with 16 adjective-pairs.		
Patterns of hanging objects		5×5	7×7
	Flat		
	Convex		
	Wave		
Procedure	0.	Explanation of experiment procedure	
	1.	Wear an S-VR and watch each samples	
	2.	Ask questions orally while watching each sample. Have them answer with numbers and the experimenter fills out the evaluation sheet	
	3.	1-2 Repeat	

5 RESULTS OF SECOND EXPERIMENT - THE CHARACTERISTIC OF MOD AND CG

We perform two-way analysis of variance with each of adjective pair and pattern of space, and clarify characteristics of Mod and CG from multiple comparison. In addition, we compare Mod and CG by factor analysis and considered their characteristics. We considered not only the merit of those, but also the **characteristics** as an indicator.

5.1 The Characteristic indicated by Adjective-Pairs

First of all, we make a comparison focused on adjective-pairs. The average score per adjective-pair is shown in Fig.2. For items with significant differences, $p < 0.05$ was indicated as ** and $0.05 < p < 0.1$ as *.

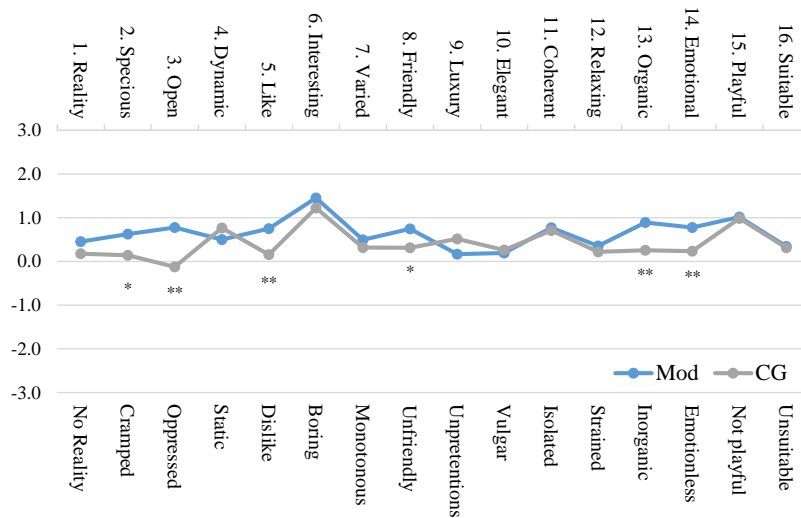


Figure 2 Average score per adjective-pair (n = 126).

13. Organic, 5. Like, 14. Emotional, and 3. Open, a significant difference was seen in the scales score average. Mod was evaluated as "Organic", "Like" and "Emotional" than CG. The reason for this was supposed that Mod is made by hand. In addition, it was shown that the model is "Open", CG is easy to give "Oppressed" impression. Moreover, it was significant at the 10% level, in 8. Friendly, CG tends to be evaluated as "Unfriendly" from the difficulty of making it using specialized software.

Also, although significant difference was not shown, in the item of 9. Luxury, CG can be evaluated as "Luxury" to some extent from the refinement made digitally. The item 6. Interesting was highly evaluated both in model and CG. 7. Varied, 10. Elegant, 11. Coherent, 12. Relaxing, 15. Playful, and 16. Suitable items, the difference between model and CG does not significantly affect the impression of the space.

5.2 The Characteristic indicated by Patterns

Next, we focused on patterns and compared the spatial impressions. The average score per pattern is shown in Fig.3. For items with significant differences, $p < 0.05$ was indicated as ** and $0.05 < p < 0.1$ as *.

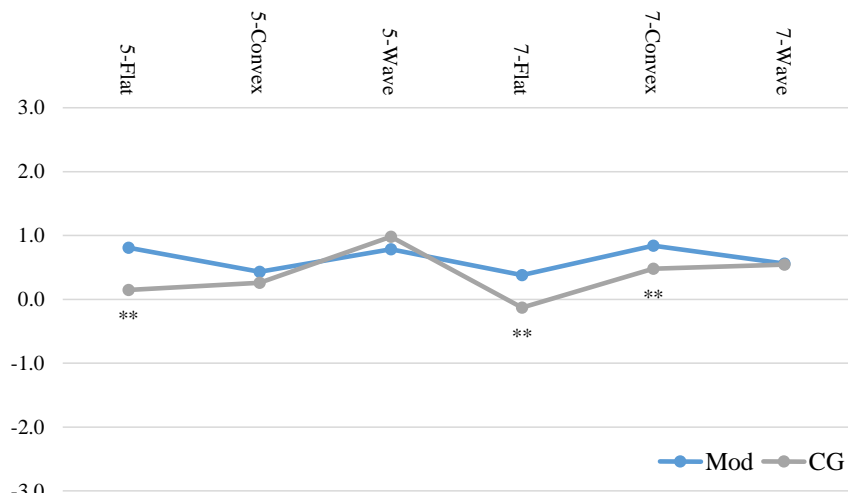


Figure 3 Average score per pattern (n = 126).

5-Flat, 7-Flat, 7-Convex, and significant difference was shown between Mod and CG. "Flat" tends to be highly evaluated by Mod. In addition, by Mod, every pattern gave a good impression, alternatively, according to the simple main effect test, the method of Bonferroni which is a parametric test for multiple comparison was used, and significant difference was not shown in the evaluation scale scores between all patterns.

In CG, the difference in the impression due to the pattern of space became clear. However, in the model, the difference in the pattern of the space is less likely to influence the impression, and whichever pattern is similar impression. As a result, when comparing impressions using a model, it is necessary to pay attention to this characteristic. In CG, the difference in the impression due to the pattern of space became clear. In particular, "Wave" tended to be evaluated in CG.

5.3 The Characteristic indicated by Factor Analysis

Subsequently, we compared the model and CG by factor analysis with the spatial impression tendency obtained from the above investigation. For the extraction of factors, we adopted the least squares method without weighting, deleted 4. Dynamic, 10. Elegant, and 11. Coherent that those commonalities were less than 0.3, and pro-max rotation was performed. Thereby four factors named "Active" "Dynamic" "Nature" "Gorgeous" were extracted as latent items of space impression.

Mod tended to have a high "Natural / Dynamic factor", and it was evaluated as "friendly", "spacious" and "open". On the other hand, CG tended to have a high "Gorgeous factor", and it was evaluated as "luxurious."

6 CONCLUSIONS

In this research, while investigating the spatial simulation experience by S-VR, simple VR headset with the smartphone, we clarified the characteristics of the spatial impression which is felt by the difference between model and CG expressing VR space. In addition to characteristics clarified in this research, considering physical conditions and the time to create Mod, for simulation comparing multiple patterns, it is best to use CG as a space expression medium. While, for instance presentation, in the case of expecting to give a better impression to the space, it is effective to use Mod. The summary of those characteristics is shown below (Table 3).

Table 3 Summary of characteristics of Mod and CG

	Scale Model	CG
Impression	"Like", "Open", "Friendly"	"Oppressed", "Luxury"
Pattern	"Flat", Resistant to patterns	"Wave"
Factor	"Natural factor", "Dynamic factor"	"Gorgeous factor"
Summary	To show better, for presentation	To compare each, for simulation

This result suggest that it is necessary to select the VR space expression medium suitable for the purpose and to give consideration to the impression in spatial simulation experiences using VR technology.

Our tasks in the future research are experiments using a small scale model of 1/50 to 1/100, relection of samples, by hanging objects in this experiment, used for impression evaluation. Moreover, it is necessary to increase the number of adjective pairs and to confirm the impression of model and CG which were not shown this time.

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