Journal of Positive School Psychology
2022, Vol. 6, No. 4, 10282–10291 http://journalppw.com

A Study on Satisfaction with Virtual Object Manipulation in Metaverse Based on Mixed Reality

Yujin Choi [1], Yoon Sang Kim [2*]

[1] BioComputing Lab, Department of Computer Science and Engineering, Korea University of Technology and Education (KOREATECH), Cheonan, Republic of Korea.
[2] BioComputing Lab, Institute for Bio-engineering Application Technology, Department of Computer Science and Engineering, Korea University of Technology and Education (KOREATECH), Cheonan, Republic of Korea.*
Email: [1] ekgkrha@koreatech.ac.kr, [2] yoonsang@koreatech.ac.kr*

Abstract

As people begin to notice metaverse, various metaverse applications have been implemented. Mixed reality (MR) is one of the representative technologies used to implement metaverse applications. MR-based metaverse application makes users achieve goals by manipulating a virtual object. Since virtual object manipulation is the main means to achieve the goals, the satisfaction of the virtual object manipulation can have a major influence on the overall satisfaction of the application. Conventional studies on MR-based metaverse applications mainly focused on developing a metaverse application with a specific purpose and evaluating the satisfaction of the developed application. However, studies on the effect of virtual object manipulation on user satisfaction considering the characteristics of MR are insufficient. Therefore, in this paper, we studied the satisfaction with virtual object manipulation in metaverse based on MR. For this, experiments using virtual objects were conducted on the subjects, and the results were analyzed. Satisfaction were analyzed based on two properties (manipulation property and virtual object property). Manipulation type, object moving type, object position, object size, and object color showed significant differences, whereas object scaling type did not show significant differences.

Keywords: Metaverse, Mixed Reality, Virtual object manipulation, Satisfaction

I. INTRODUCTION

COVID-19, which recently caused a global pandemic, reduced or suspended various face-to-face (FF) activities, and attempts to convert existing FF activities to non-face-to-face (NFF) activities are increasing [1-2]. However, various NFF activities converted to these attempts provided a relatively low sense of immersion compared to FF activities [3-4]. In order to overcome the limitation of low immersion in NFF activities, a concept that has recently been noticed is the metaverse [5-7].

Metaverse is a compound word of the Greek prefix meta, meaning post, after or beyond, and the universe. Among the various types of metaverse applications, one that has recently received particular attention is a mixed reality-based metaverse application (hereafter MRMA), and research is being conducted to apply it to various fields such as education, entertainment, and games [8-12]. MRMA allows users to achieve goals through virtual object manipulation, such as moving objects to a specific area or selecting target objects. Since virtual object manipulation is the main means to achieve the goals, the satisfaction of the virtual object manipulation can have a major influence on the overall satisfaction of the application. However, conventional studies on MRMA mainly focused on developing MRMA with a specific purpose and evaluation of satisfaction of the developed applications [8-12], and studies analyzing the effects of factors related to virtual object manipulation on user satisfaction were insufficient.

In this paper, we analyze satisfaction with virtual object manipulation in metaverse based on mixed reality (MR). In order to analyze satisfaction, the following steps were performed: 1) experiment conduct, 2) experimental result analysis. First, in the experiment conduct step, the subjects conduct the experiment by manipulating virtual objects in MRMA under different manipulation properties and virtual object properties. Second, in the experimental result analysis step, satisfaction with virtual object manipulation in MRMA measured during the experiment is analyzed.

This paper is composed as follows. In section 2, we explain related works. In section 3, we conduct an experiment based on virtual object manipulation and analyze the experimental results. Finally, in section 4, we present conclusions and future works.

II. RELATED WORKS

The metaverse is largely composed of Augmented Reality (which is composing metaverse, not the technology itself), Life Logging, Mirror Worlds, and Virtual Worlds [13]. Among them, Augmented Reality and Life Logging are elements corresponding to the augmentation continuum and are mainly implemented using augmented reality (AR) technology. On the other hand, Mirror Worlds and Virtual Worlds are elements that correspond to the simulation continuum and are mainly implemented using virtual reality (VR) technology.

Recently, the concept of MR has been used in several studies, and MR refers to a mixture of real and virtual objects within a single display, a combination of AR and VR, and an alternative to AR [14]. In particular, when looking at MR in terms of a combination of AR and VR, the MR-based metaverse can serve as a pathway for making the elements corresponding to the augmented continuum and the elements corresponding to the simulation continuum compatible with each other.

Recently, studies on such MR-based metaverse applications have been actively carried out [8-12]. MacCallum, K. et al [8] provided experiences for teachers to create mobile AR experiences using the Metaverse AR tool and conducted a survey accordingly. As a result of the survey, teachers confirmed that the Metaverse AR tool could lead to new ideas applicable to education. Marini, A. et al. [9] analyzed the learning results when using the Metaverse app, which is mobile AR software for science courses for students. As a result of the analysis, it was confirmed that the Metaverse app improved the students' learning effect and made the students more interested in learning. Rhee, T. et al. [10] implemented a remote collaboration application for shared workspace scenarios and performed user evaluation. As a result of the evaluation, users responded positively to remote collaboration and co-presence with partners, and it was confirmed that they had high satisfaction with the system. Wang, P. et al. [11] proposed a VR-Spatial AR remote collaborative system and performed user evaluation. As a result of the evaluation, it was confirmed that the user had high satisfaction with the system's usability. Estudante, A. et al. [12] proposed an educational escape game of numeric mobile AR version and conducted an experiment for students. As a result of the experiment, it was confirmed that the students were able to enjoy the game without a teacher fully and that it increased the students' motivation.

Most of the conventional studies above implemented MRMA, which allows subjects to achieve their goals through virtual object manipulation, and the satisfaction (usability, preference, and etc.) of the implemented MRMA was evaluated. That is, virtual object manipulation that the subject is induced to perform was not considered in the above conventional studies. In each of the MRMA in the above studies, the following virtual object manipulations were mainly performed: Selecting, Moving, Rotating, and Scaling. In addition, virtual object manipulation properties that can be used in MRMA are various depending on the goals and scenarios of MRMA, and user satisfaction may vary according to each object manipulation method. Also, even if the virtual object manipulation property is fixed, the satisfaction felt by the user may be greatly changed by the properties of the virtual object to be manipulated, such as size, color, position, and the like. Therefore, it is required to conduct a study on virtual object manipulation in MRMA considering the virtual object manipulation properties and virtual object properties.

III. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Environment

An MRMA was implemented to analyze user satisfaction based on virtual object manipulation in MR-based metaverse. The experimental environment using the implemented application is shown in Figure 1.

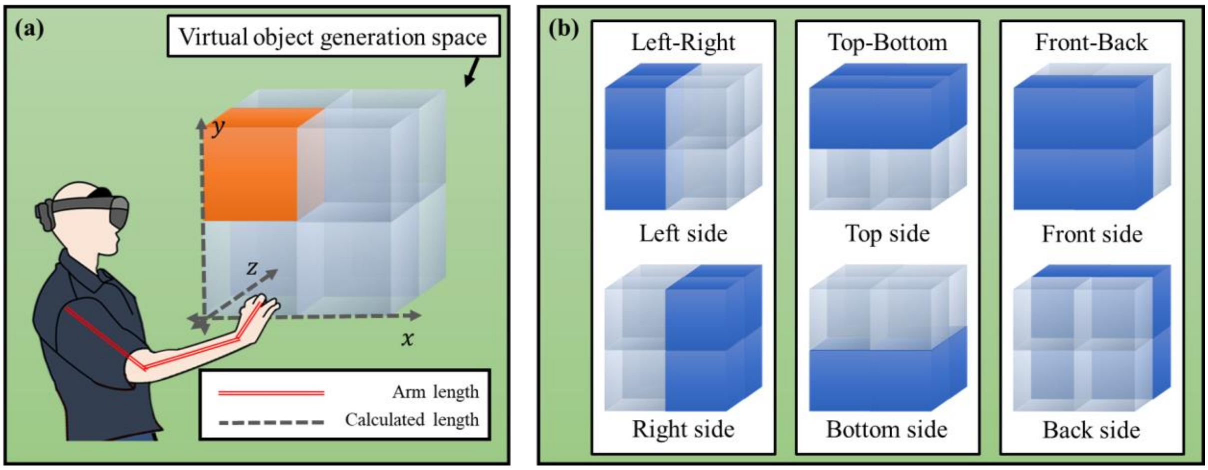

Figure 1. *Experimental environment: (a) virtual object generation space and subject, (b) virtual object generation position*

Figure 1 (a) shows the subject using the application. The subject interacts with a virtual object generated in the virtual object generation space represented by the gray cube in (a). The virtual object generation space is the maximum space in which a virtual object can be generated and was set through a calculated length (gray dashed line) from the subject's arm length (red double line). This borrowed the method of [15] and was adopted to prevent bias in experimental results due to differences in the body of each subject. In addition, in order to prevent problems caused by the subject's adaptation to the experiment, the virtual objects were set to appear in random order at random locations. In this experiment, the location of the virtual object is defined as a combination of the three types of sides expressed in blue in Figure 1 (b), and the location of the virtual object generated in the orange cube in Figure 1 (a) is an example left-top-front.

In order to confirm the effect of virtual object manipulation on satisfaction, it is required to set target factors. In this study, the type of manipulation and the properties of virtual objects were set as target factors according to the results of the investigation in section 2. The types of manipulations covered in this study are as follows: Selecting, Moving, Rotating, and Scaling. Next, the properties of the virtual object covered in this study are as follows: Position, Size, and Color.

Since the visibility of virtual objects in an MR-based metaverse environment can be affected by even a small difference in ambient illuminance, a constant average illuminance was maintained through artificial lighting (140 lux).

3.2 Methodology

For the experiment, 24 subjects in their twenties [16] were recruited, and the subjects were sufficiently informed about the experimental location and the experiment procedure. It was recommended that each subject who was confirmed to participate in the experiment took part in the experiment with sufficient rest before the experiment.

The subjects who arrived at the experimental location were informed about the experiment procedure repeatedly, and after the explanation, all subjects filled out the experimental consent form. After filling out the experimental consent form, a demographic questionnaire, including age, gender, etcetera, was asked, and the arm length of the subject, which is used to set virtual object generation space in Figure 1, was measured. After all the questionnaires and the subject's arm length measurement were completed, the subjects moved to the guided experimental space, sat in a designated seat, and wore Microsoft Hololens2 [17].

In the experiment, the task of selecting a target virtual object generated in a random position was given to each subject. Tasks were classified into tasks according to the manipulation properties (Manipulation type, Object Moving type, Object Scaling type) and tasks according to virtual object properties (Position, Size, Color). In order to prevent the experimental results from spoiling due to the manipulation property, the manipulation property in tasks according to the virtual object properties was unified as Selecting.

As shown in Figure 2, virtual object manipulation is performed in the order of object searching, object manipulation, and satisfaction input

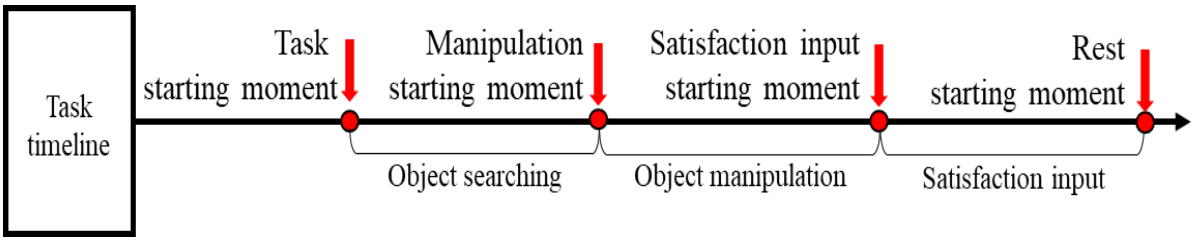

***Figure 2.** Virtual object manipulation procedure*

Object searching is performed between the task starting moment and the manipulation starting moment and is a process in which the subject finds the created target object. Object manipulation is performed between the manipulation starting moment and the satisfaction input starting moment and is a process in which the subject manipulates the target object according to a given manipulation property. Satisfaction input is performed between the satisfaction input starting moment and the rest starting moment and is a process in which the subject inputs satisfaction with the task. Whenever subjects complete one task (after the Satisfaction input starting moment in Figure 2), they are asked to enter their user satisfaction with the task, and satisfaction is measured on a Likert 5 scale from 1 to 5. After the task is done, the subject is given a short break.

All of the above research procedures were conducted according to the guidelines of the Declaration of Helsinki, and we obtained approval by the Institutional Review Board of KOREATECH in advance (approval on May 26, 2021).

3.3 Results and discussion

3.3.1 Manipulation property

Regarding the type of manipulation, satisfaction with the Selecting, Moving, Rotating, and Scaling manipulations mentioned in section 3.1 was analyzed from the following three points: satisfaction according to manipulation type, satisfaction according to object moving type, and satisfaction according to object scaling type.

Measured satisfaction according to manipulation type is shown in Figure 3.

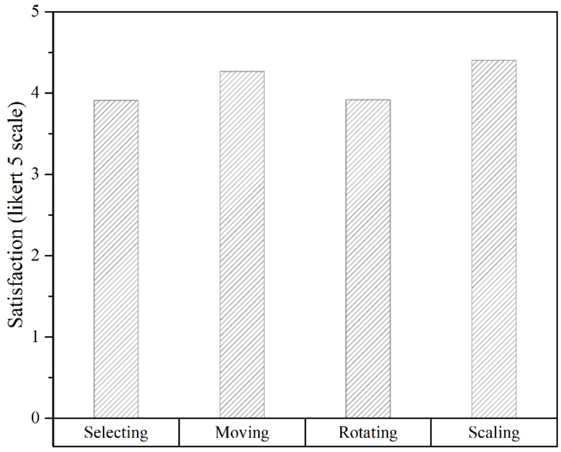

Figure 3. *Satisfaction according to manipulation type*

As shown in Figure 3, it was confirmed that overall satisfaction was higher when the manipulation type was Selecting or Rotating than Moving or Scaling. In order to confirm whether the difference is significant, the Kruskal-Wallis H test, which is a non-parametric test, and the result is shown in Table 1.

Table 1. *Results of Kruskal-Wallis H test for satisfaction according to manipulation type*

	Score
Chi-square	9.599
Df	3
Asymp. Sig.	.022

As a result of the Kruskal-Wallis H test, as shown in Table 1, the significance level was lower than 0.05. Based on this, it was confirmed that there was a significant difference in satisfaction according to the manipulation type. Meanwhile, Table 2 shows the results of the Mann-Whitney U test, which is a non-parametric test for each manipulation type.

Table 2. *Results of Mann-Whitney U test for satisfaction according to manipulation type*

	Mann-Whitney U	Z	p
Selecting – Moving	161	-2.629	0.009
Selecting – Rotating	264	-0.499	0.618
Selecting – Scaling	180	-2.257	0.024
Moving – Rotating	192.5	-1.975	0.048
Moving – Scaling	278	-0.208	0.835
Rotating – Scaling	206	-1.704	0.088

As a result of the Mann-Whitney U test, as shown in Table 2, it was confirmed that Moving has a relatively low satisfaction compared to Selecting and Rotating, and Scaling has a relatively low satisfaction compared to Selecting. This is judged because the hand position changes according to the object manipulation in Moving and Scaling, but the change in Selecting and Rotating is small.

Measured satisfaction according to object moving type is shown in Figure 4.

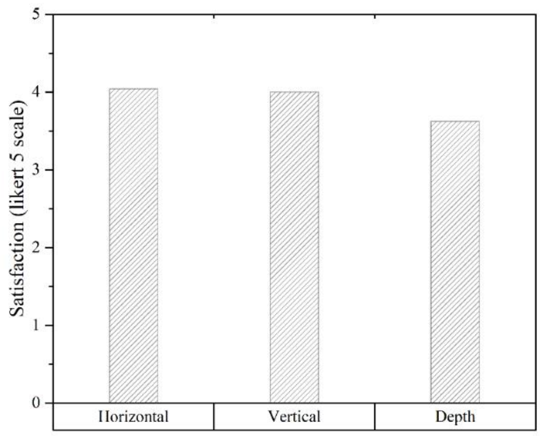

Figure 4. *Satisfaction according to object moving type*

As shown in Figure 4, it was confirmed that overall satisfaction was higher when the object moving type was Horizontal or Vertical than Depth. In order to confirm whether the difference is significant, the Kruskal-Wallis H test, which is a non-parametric test, and the result is shown in Table 3.

Table 3. *Results of Kruskal-Wallis H test for satisfaction according to object moving type*

	Score
Chi-square	6.498
Df	2
Asymp. Sig.	.039

As a result of the Kruskal-Wallis H test, as shown in Table 3, the significance level was lower than 0.05. Based on this, it was confirmed that there was a significant difference in satisfaction according to the object moving type. Meanwhile, Table 4 shows the results of the Mann-Whitney U test, which is a non-parametric test for each object moving type.

Table 4. Results of Mann-Whitney U test for satisfaction according to object moving type

	Mann-Whitney U	Z	p
Horizontal – Vertical	1080	-0.568	0.57
Horizontal – Depth	853	-2.329	0.02
Vertical – Depth	900	-1.986	0.047

As a result of the Mann-Whitney U test, as shown in Table 4, it was confirmed that Depth has a relatively low satisfaction compared to Horizontal and Vertical. This is judged because Horizontal and Vertical have experienced a lot of existing 2D-based applications but little experience with Depth.

Measured satisfaction according to object scaling type is shown in Figure 5.

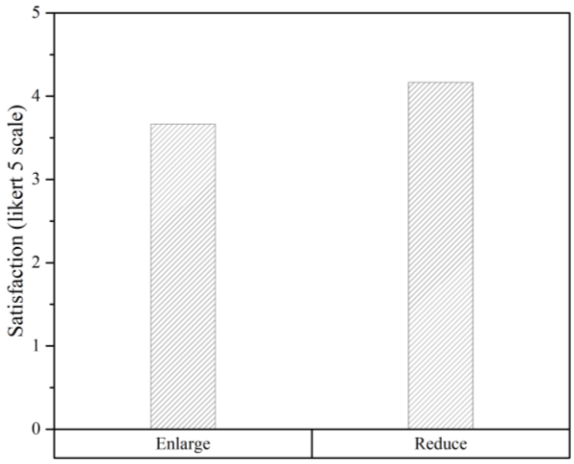

Figure 5. *Satisfaction according to object scaling type*

As shown in Figure 5, it was confirmed that overall satisfaction was higher when the object moving type was Reduce than Enlarge. In order to confirm whether the difference is significant, the Mann-Whitney U test, which is a non-parametric test, and the result is shown in Table 5.

Table 5. *Results of Mann-Whitney U test for satisfaction according to object scaling type*

	Score
Mann-Whitney U	960
Z	-1.488
p	0.137

As a result of the Mann-Whitney U test, as shown in Table 5, the significance level was higher than 0.05. Based on this, it was confirmed that there was no significant difference in satisfaction according to the object scaling type.

3.3.2 Virtual object property

Regarding virtual object properties, satisfaction according to Position, Size, Color, and Floating properties mentioned in section 3.1 was analyzed from the following three points: satisfaction according to object position, satisfaction according to object size, and satisfaction according to object color.

Measured satisfaction according to object position is shown in Figure 6.

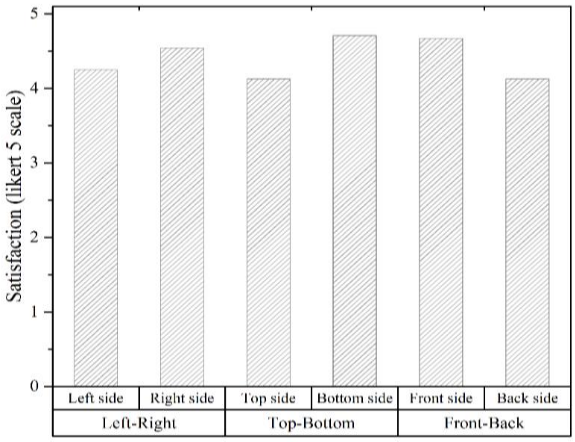

Figure 6. *Satisfaction according to object position*

As shown in Figure 6, it was confirmed that satisfaction was higher in the case of Right rather than Left, Bottom rather than Top, and Front rather than Back. In order to confirm whether the difference is significant, the Mann-Whitney U test, which is a non-parametric test for each side pair, and the result is shown in Table 6.

Table 6. *Results of Mann-Whitney U test for satisfaction according to object position*

	Mann-Whitney U	Z	p
Left-Right	201.5	-1.987	0.047
Top-Bottom	186.5	-2.362	0.018
Front-Back	192	-2.209	0.027

As a result of the Mann-Whitney U test, as shown in Table 6, the significance level was lower than 0.05. Based on this, it was confirmed that there was a significant difference in satisfaction according to the object position. Here, the Left-Right pair result is judged to be a possible result because all the subjects participating in the experiment were right-handed. In the case of right-handed people, the satisfaction of manipulating the virtual object located on the Right side was higher than that of manipulating the virtual object located on the Left side. However, the opposite result is expected for the left-handed person. Therefore, the Left-Right pair result is required to be adjusted properly and applied according to the main hand case.

Measured satisfaction according to object size is shown in Figure 7.

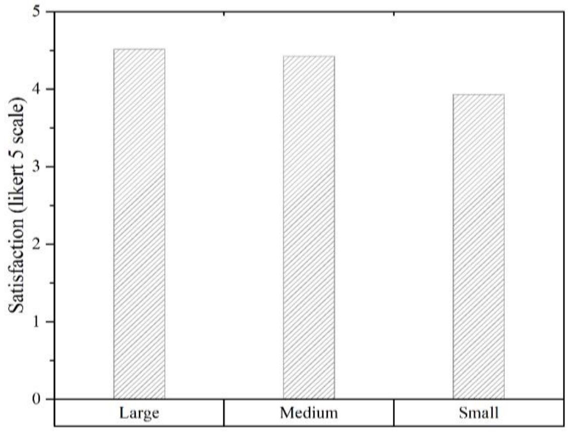

Figure 7. *Satisfaction according to object size*

As shown in Figure 7, it was confirmed that overall satisfaction was higher when object size was Large (200% of default size) or Medium (100% of default size) than Small (50% of default size). In order to confirm whether the difference is significant, the Kruskal-Wallis H test, which is a non-parametric test, and the result is shown in Table 7.

Table 7. *Results of Kruskal-Wallis H test for satisfaction according to object size*

	Score
Chi-square	8.751
Df	2
Asymp. Sig.	.013

As a result of the Kruskal-Wallis H test, as shown in Table 7, the significance level was lower than 0.05. Based on this, it was confirmed that there was a significant difference in satisfaction according to the object size. Meanwhile, Table 8 shows the results of the Mann-Whitney U test, which is a non-parametric test for each object size type.

Table 8. *Results of Mann-Whitney U test for satisfaction according to object size*

	Mann-Whitney U	Z	p
Small – Medium	189.5	-2.055	0.04
Small – Large	166.5	-2.548	0.011
Medium – Large	252.5	-0.754	0.451

As a result of the Mann-Whitney U test, as shown in Table 8, it was confirmed that Small has a relatively low satisfaction compared to Medium and Large. This is judged because due to the characteristics of gesture-based manipulation, the size of the hand, which is a tool for manipulation, is fixed, and thus manipulation becomes difficult when the virtual object becomes smaller than a specific size.

Measured satisfaction according to object color is shown in Figure 8.

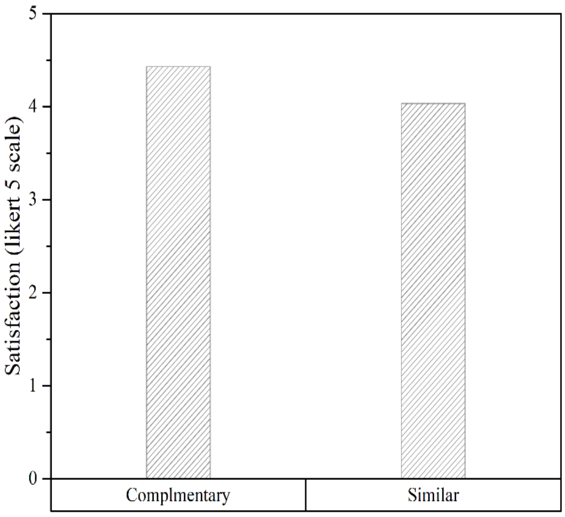

Figure 8. *Satisfaction according to object color*

As shown in Figure 8, it was confirmed that overall satisfaction was higher when object color was Complementary than Similar. In order to confirm whether the difference is significant Mann-Whitney U test, which is a non-parametric test, and the result is shown in Table 9.

Table 9. *Results of Mann-Whitney U test for satisfaction according to object color*

	Score
Mann-Whitney U	175.5
Z	-2.333
p	0.02

As a result of the Kruskal-Wallis H test, as shown in Table 9, the significance level was lower than 0.05. Based on this, it was confirmed that there was a significant difference in satisfaction according to the object color. This is judged because the visibility of the virtual object decreases in the case of Similar than Complementary.

IV. CONCLUSION AND FUTURE WORKS

In this paper, we analyzed satisfaction with virtual object manipulation in metaverse based on MR. For the analysis, we implemented the MRMA providing virtual object manipulation and conducted an experiment to measure satisfaction according to manipulation and virtual object properties. For the experiment, the subject wore Hololens2 [17] in sitting position and manipulated a virtual object generated at a random location according to the task. During the experiment, satisfaction (Likert 5 scale) was measured whenever each task was completed, and through this, satisfaction with virtual object manipulation was analyzed. From experimental results, the satisfactions were analyzed according to the manipulation property and according to the virtual object property, respectively. As a result of satisfaction analysis according to the manipulation properties, the satisfaction of Moving among manipulation types was lower than that of other types, and the one of the Depth movement among object moving types had the lowest satisfaction. However, the difference according to the object scaling type was not significant. As a result of satisfaction analysis according to the virtual object properties, satisfaction was low when the object position was located on the Left (right-handed case), Top, and Back, and the satisfaction was low when the size of the object was small. In addition, when the object color was similar to the surrounding environment, satisfaction was low. From the results, it was confirmed that the object manipulation provided in the MRMA could have a significant effect on user satisfaction.

V. ACKNOWLEDGMENTS

This work was supported by Electronics and Telecommunications Research Institute(ETRI) grant funded by ICT R&D program of MSIT/IITP[2020-0-00537].

REFERENCES

1. Embrett, M., Liu, R. H., Aubrecht, K., Koval, A., & Lai, J. (2021). Thinking together, working apart: leveraging a community of practice to facilitate productive and meaningful remote collaboration. International Journal of Health Policy and Management, 10(9), 528-533.
2. Favale, T., Soro, F., Trevisan, M., Drago, I., & Mellia, M. (2020). Campus traffic and e-Learning during COVID-19 pandemic. Computer networks, 176, 107290.
3. Daft, R. L., & Lengel, R. H. (1983). Information richness. A new approach to managerial behavior and organization design. Texas A and M Univ College Station Coll of Business Administration.
4. García-Peñalvo, F. J., Corell, A., Abella-García, V., & Grande-de-Prado, M. (2021). Recommendations for mandatory online assessment in higher education during the COVID-19 pandemic. In Radical solutions for education in a crisis context (pp. 85-98). Springer, Singapore.
5. Ifdil, I., Situmorang, D. D. B., Firman, F., Zola, N., Rangka, I. B., & Fadli, R. P. (2022). Virtual reality in Metaverse for future mental health-helping profession: an alternative solution to the mental health challenges of the COVID-19 pandemic. Journal of Public Health.
6. Werner, H., Ribeiro, G., Arcoverde, V., Lopes, J., & Velho, L. (2022). The use of metaverse in fetal medicine and gynecology. European Journal of Radiology, 150.
7. Lee, H., Woo, D., & Yu, S. (2022). Virtual Reality Metaverse System Supplementing Remote Education Methods: Based on Aircraft Maintenance Simulation. Applied Sciences, 12(5), 2667.
8. MacCallum, K., & Parsons, D. (2019, September). Teacher perspectives on mobile augmented reality: The potential of metaverse for learning. In World Conference on Mobile and Contextual Learning (pp. 21-28).
9. Marini, A., Nafisah, S., Sekaringtyas, T., Safitri, D., Lestari, I., Suntari, Y., ... & Iskandar, R. (2022). Mobile Augmented Reality Learning Media with Metaverse to Improve Student Learning Outcomes in Science Class. International Journal of Interactive Mobile Technologies, 16(7).
10. Rhee, T., Thompson, S., Medeiros, D., Dos Anjos, R., & Chalmers, A. (2020). Augmented virtual teleportation for high-fidelity telecollaboration. IEEE transactions on visualization and computer graphics, 26(5), 1923-1933.
11. Wang, P., Bai, X., Billinghurst, M., Zhang, S., Han, D., Sun, M., ... & Han, S. (2020). Haptic feedback helps me? A VR-SAR remote collaborative system with tangible interaction. International Journal of Human–Computer Interaction, 36(13), 1242-1257.
12. Estudante, A., & Dietrich, N. (2020). Using augmented reality to stimulate students and diffuse escape game activities to larger audiences. Journal of Chemical Education, 97(5), 1368-1374.
13. Smart, John, Cascio Jamais, and Paffendorf Jerry. 2007. Metaverse Road Map: Pathways to the 3D Web. Metaverse: A Cross-Industry Public Foresight Project. Available online: https://www.metaverseroadmap.org/overview/index.html (accessed on 13 May 2022).
14. Speicher, M.; Hall, B.D.; Nebeling, M. What is Mixed Reality? In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, Glasgow, UK, 4–9 May 2019; ACM: New York, NY, USA, 2019; pp. 1–15.

15. Choi, Y., Son, W., & Kim, Y. S. (2021). A Study on Interaction Prediction for Reducing Interaction Latency in Remote Mixed Reality Collaboration. Applied Sciences, 11(22), 10693.
16. Dey, A., Billinghurst, M., Lindeman, R. W., & Swan, J. (2018). A systematic review of 10 years of augmented reality usability studies: 2005 to 2014. Frontiers in Robotics and AI, 5, 37.
17. Microsoft HoloLens2. Available online: https://www.microsoft.com/en-us/hololens/hardware (accessed on May 2022)