Journal of Digital Media & Culture Technology
ISSN 2983-0664(p) 2983-0850(e)
Vol.4, No.1, June (2024), pp.49-59
http://dx.doi.org/10.29056/jdmct.2024.06.05

An Analysis of User Experiences with Virtual Reality Head-Mounted Displays in Museum Exhibitions

Yeun-Hee Kim[1]

Abstract

With the rapid technological advancement in modern society, the virtual reality (VR) industry has become increasingly important and in demand, and this change has also brought about changes in museum exhibitions. Wearing a VR HMD (Head-Mounted Display) to view artworks provides visitors with immersion and interactivity. However, there are a number of problems that visitors experience including physical problems such as headaches, dizziness, and simulator sickness, and psychological problems such as disorientation, fear, and anxiety. Research has been conducted to address these issues, but solutions are still lacking. Therefore, this study aims to apply grounded theory, a qualitative research method, to qualitatively analyze the discomfort felt by visitors in museum HMD wearable artworks and propose alternative solutions. To do this, this paper first interviewed visitors who had experience wearing HMDs. All interview transcripts were documented, and a paradigmatic model was constructed through open coding, axial coding, and selective coding. As a result, 61 concepts, 6 superordinate categories, and 11 subcategories were derived. Based on the results of the analysis, this paper conducted a qualitative study on the inconveniences of visitors when creating HMD wear-based works, and it is expected that multidisciplinary research on HMD wear-based works will be conducted based on the results of this study.

Keyword : Virtual reality (VR), HMD, museum, grounded theory, Simulator sickness

1. Introduction

Virtual Reality (VR) technology is being recognized as one of the growth engines driving the Fourth Industrial Revolution. In addition, the development of VR content is expected to accelerate due to fifth-generation mobile communication (5G) technology [1]. Among the various virtual reality implementation devices, HMD (Head Mounted Display) based virtual reality implementation technology is gaining attention. In recent years, VR has been rapidly utilized in various fields including performance, exhibition, and education. As VR technology is expanding into the cultural field and becoming a major cultural activity, changes have emerged in various areas of museums, including exhibitions, education, and experiences, due to the adoption of VR HMDs.

For museum exhibits, wearing a VR HMD to view artwork provides immersion and interactivity for

1 Department of Arts & Museum, Kookmin University, Seoul, Korea [Professor]
e-mail: tofree1@kookmin.ac.kr

Received(April 21, 2024), Review Result(1st: May 9, 2024), Accepted(June 7, 2024), Published(June 30, 2024)

visitors. However, visitors have been experiencing a variety of problems after wearing HMDs including physical problems such as headaches, dizziness, and simulator sickness, and psychological problems such as disorientation, fear, and anxiety. Those issues has been studied in much research, but solutions are still lacking. Therefore, this study conducted a literature review focusing on previous studies and monographs on VR HMDs, and applied grounded theory, a qualitative research method, to investigate and analyze the discomfort felt by visitors in museum HMD wear-based works. To do this, this paper first interviewed visitors who had experience wearing HMDs. All interview transcripts were documented, and a paradigmatic model was constructed through open coding, axial coding, and selective coding. Based on the analysis of the discomfort felt by visitors in museum HMD wearable artworks, this paper lastly proposes alternative solutions.

2. Theoretical background

2.1 Virtual Reality (VR)

There are many definitions of VR, but it generally refers to a technology that utilizes an HMD to showcase visual results. A similar concept to VR is AR (augmented reality), which is a technology that superimposes virtual images and phenomena on real-world spaces to create a variety of environments in both real and virtual spaces [2]. The historical background of VR can be traced back to the primitive cultures of the Upper Paleolithic period, when shamans attempted to merge virtual reality with the real world by communicating with the realm of the gods to help humans survive, as seen in ancient Egyptian murals. Ancient Egyptian murals depict Avinus, who has the head of a jackal and the body of a human, leading the dead to the court of Osiris and connecting the virtual world of death with reality as a mediator between life and death. The first machine similar to today's VR devices dates back to 1962 with the Sensorama Simulator developed by Morton Hayrig in the United States [3]. The term ‘virtual reality’ was popularized in 1987 by Jaron Lanier, while the 90s saw early consumer VR products like the SEGA VR headset. The 2000s brought more research into HMDs, tracking, and input devices. But it was in 2010 when Palmer Luckey designed the Oculus Rift prototype, followed by a hugely successful 2012 Kickstarter, that sparked the modern consumer VR revolution. Major tech companies released numerous VR headsets in the following years, while VR applications rapidly expanded across gaming, training, marketing, real estate, and many other industries, with continuing advances in areas like wireless, high-resolution displays, and integration of AI, haptics and other cutting-edge technologies [4][5].

2.2 HMD

HMD stands for Head Mounted Display, which is a device that displays two images, left and right, and is worn on the head as shown in [Fig. 1]. There are smartphone-mounted, wired, and standalone HMDs that deliver virtual reality [6]. The first person to propose an HMD system was Ivan Sutherland, who was working at Harvard University in 1968. It was a groundbreaking idea at the time, but they were too large and heavy to use and lacked realism and immersion. Since then, HMDs have evolved in military and aerospace applications [3]. HMD-based virtual reality is a type of enhanced visual realism that goes beyond the experience of a combination of hardware or a specialized form of tele-presence, such as tele-robotics or desktop virtual reality. It is important to note that HMD-based virtual reality video is not based on perception alone, but is experienced visually [7].

[Fig. 1] HMD and VR

2.3 VR in museum and exhibition

VR technology has opened up new possibilities for enhancing the museum experience, allowing visitors to immerse themselves in exhibits in ways that were not previously possible. As shown in [Fig 2] and [Fig 3], many museums now offer virtual tours of their galleries and exhibitions. Visitors can explore the museum from anywhere in the world. These tours often use 360-degree panoramic images or videos to provid an immersive experience that simulates being physically present in the museum [8]. In addition, VR can be used to create interactive educational experiences that bring historical events, scientific concepts, or cultural traditions to life [9]. For example, visitors can virtually step into ancient civilizations, explore the solar system, or witness significant historical moments. VR can also be used as a tool for exhibition designers to visualize and experiment with different layouts and configurations before physically setting up an exhibition. While VR technology is still evolving, many museums are embracing it as a way to enhance visitor engagement, provide new perspectives on their collections, and make their exhibits more accessible and interactive. However, it is important to note that VR experiences are meant to complement, rather than replace, the physical museum experience.

[Fig. 2] The Franklin Institute in 2016

[Fig. 3] The Metoropolitan Museum of Art

3. Research Methods

3.1 Grounded Theory

Grounded theory methodology is the exploration of a real-world field to gain new understanding of a social phenomenon where little is known about it or where it already exists [10]. It is called grounded theory because the theory is developed through the analysis of the collected data, and the focus is not on generalization, but on the logical connection between the causal, mediating, and countermeasure outcomes of the core phenomenon [11]. Therefore, grounded theory is a qualitative research methodology that is useful for understanding human and organizational social, psychological, and structural phenomena that are difficult to capture through other research methodologies [12].

3.2 Selecting and interviewing research participants

3.2.1. Selecting study participants

As list in [Table 1], the study was conducted through eight interviews, and the interviewees were selected based on their experience wearing VR HMDs for exhibition viewing.

[Table 1] Study Participant Personal Information

No.	Age	Sex	Profession	Number of prior HMD experiences
1	20s	M	University Student	2
2	20s	M	University Student	3
3	20s	F	Worker	3
4	20s	F	University Student	4
5	30s	M	Worker	1
6	40s	M	Worker	2
7	40s	F	Worker	2
8	50s	F	Housewife	1

3.2.2. Planning and conducting interviews

The interviews were conducted on a one-on-one basis, mostly in cafes, classrooms, etc. Since all of the participants had experienced VR HMDs in different museums, the interview questions were not specific to the VR HMD artwork, but rather to the overall HMD experience. The specific research questions were detailed in [Table 2].

[Table 2] Interviews questions

Question number	Interview questions
1	What are your thoughts on utilizing VR HMD artwork?
2	Have you been fully informed and instructed on the precautions before using a VR HMD?
3	Did you experience any discomfort or issues with wearing your HMD?
4	Have you experienced any discomfort or issues with VR HMDs, such as virtual motion sickness, headaches, or feelings of emotional isolation?

5	What do you think are the limitations of wearing an HMD?
6	Would you use your HMD again despite the issues you have with it?
7	What features of the HMD affect immersion in virtual reality?
8	What features of HMDs break immersion in virtual reality?

3.3 Data analytics

Based on the grounded theory, the data was processed in five stages. First, after the interviews, the typed documents were collected and used as raw data. Second, keywords were selected from the documents. The third step was open coding, where the keywords were used to identify and categorize the paradigms. From there, they were abstracted into 6 super-categories and 11 sub-categories. The fourth step was axial coding, which involved paradigmatically relating the six superordinate categories and 11 subcategories from the previous step of open coding. Here, according to the paradigmatic model of grounded theory, they were categorized and connected according to the six levels of causal conditions, contextual conditions, central phenomena, action/interaction strategies, mediating conditions, and outcomes. Fifth, selective coding was used to integrate the theories based on theoretical saturation.

4. Analysis results

This study selected eight participants and collected data through interviews with users who have used HMDs at least twice. Based on the collected data, open coding, axial coding, and selective coding were conducted by applying the analysis method of the grounded theory methodology proposed by Strauss and Corbin (1990. 1994).

4.1 Open coding

The results can be categorized into various concepts related to using VR HMDs in a paradigm model based on grounded theory. As shown in [Table 3], it identifies causal conditions like technological advances and interest in VR that led to the central phenomena of museums utilizing HMD systems for exhibits (the central phenomena). The contextual conditions include the benefits of HMDs like immersion and presence enabled by their digital images. However, the limitations of current VR technology like motion sickness are mediating conditions. To address the inconveniences of HMDs like improper strap material and weight distributions (action strategies), issues arise such as discomfort wearing HMDs with glasses and passive visitor experiences in third-person VR exhibits. Ultimately, the key outcome explored is the physical and psychological problems users face when wearing HMDs like simulator sickness, loss of realism, and safety risks from obstructed vision.

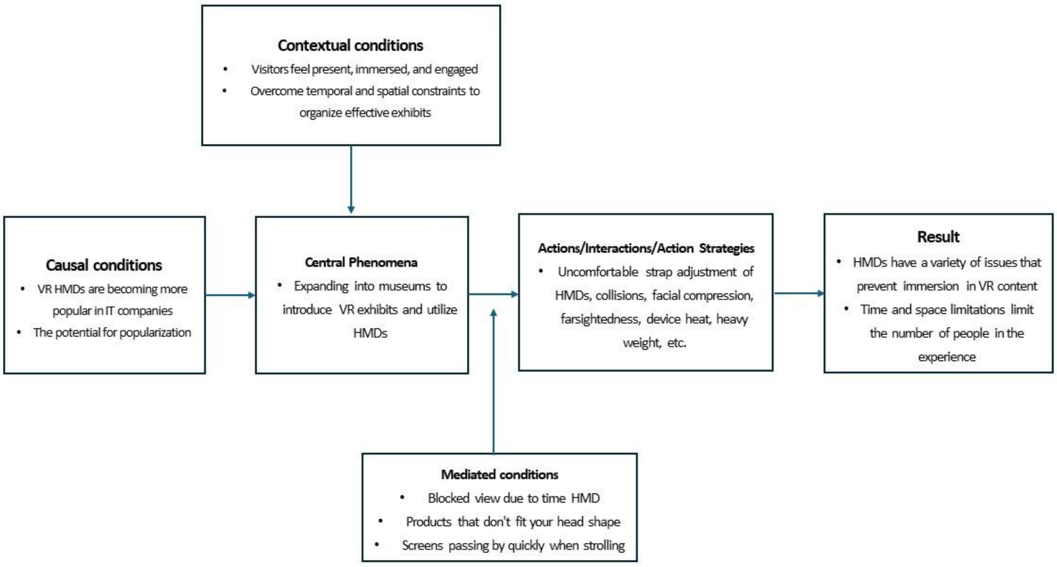
[Table 3] Categories of data in accordance with the paradigm of evidence theory for HMD.

Concepts	Subcategory	Category	Paradigms
The first virtual reality systems were flight simulators developed by the U.S. Air Force and the aviation industry in the 1940s.	Technological advances in virtual reality	Interest in Virtual Reality interest in virtual reality	Causal conditions
1. presence: the subjective feeling of being physically present in a place other than the same place, achieved through interacting with remote technology 2. immersion: the mental and physical excitement that people feel when acting in a particular state, and the feeling that actions flow naturally at the moment of heightened causal experience.	Benefits of HMDs	HMD's attributes	Contextual conditions
There are two factors that define how real the experience of virtual reality is: immersion and presence.	Characteristics of digital images by HMDs		
1. As HMD devices have become more widely available to the general public, world-renowned museums and art galleries have expanded their virtual reality exhibition booths utilizing HMD systems. 2. Virtual reality exhibitions can support viewing and learning by active selection of visitors, and can be varied and infinitely changed in content and spatial organization, making it possible to overcome temporal and spatial constraints and organize more effective exhibitions compared to previous exhibition forms. The third-person observer perspective emphasizes the fun of looking around and exploring the screen from an observer's point of view, which emphasizes the 360-degree screen feature of virtual reality, and plays a role in increasing interest and excitement in the exhibition. In the case of immersive VR, the HMD blocks all of the experiencer's view, increasing the potential for accidents. One of the major limitations of VR technology that has yet to be addressed is virtual reality motion sickness. Dizziness, nausea, and other discomfort experienced by users when experiencing VR content is a major factor that has hindered the development of the VR industry.	Utilizing HMDs for exhibits	Utilizing HMD features in museums	Central Phenomen a

The third-person observer perspective emphasizes the fun of looking around and exploring the screen from an observer's perspective, which highlights the 360-degree nature of virtual reality, and increases interest and excitement in the exhibit.	Interest and excitement in exhibits with HMDs		
In the case of immersive VR, the HMD blocks the experiencer's entire field of vision, increasing the likelihood of accidents.	Reasons for accidents in HMD wearers	Limitations of HMD technology	Mediated conditions
One of the major limitations of VR technology that has yet to be solved is virtual reality motion sickness. Dizziness, nausea, and other discomfort experienced by users when experiencing VR content is a major factor hindering the development of the VR industry.	What's holding back the VR industry		
1. The fixed belt, which is currently used as a stretchy material for HMD devices, should be made of a solid material. 2. To compensate for the forward tilt of the center of gravity due to the weight of the smartphone, it should be able to hold the center of gravity by putting weight on the back.	Addressing the challenges of using HMDs for female gamers	inconvenienc e	Actions/Int eractions/ Action Strategies
Wearing an HMD while wearing glasses increased facial discomfort and increased pressure on the nose. We found that this discomfort contributed to VR motion sickness.	Challenges of using HMDs with glasses		
Visitors who experience the exhibition from the perspective of a third-person observer through an HMD passively experience the exhibition through the video created by the artist, showing low levels of participation and planning.	Negative impact on visitors at exhibits utilizing HMDs	Issues with current HMDs	Result
Motion sickness caused by the mismatch between the image on the HMD's screen and the user's movements, or by the image moving or changing too quickly, and accidents where the user cannot see the outside world while wearing the HMD and moves while concentrating on the image on the HMD screen and bumps into objects in the real world.	Problems with wearing an HMD		

4.2 Axis coding

After open coding, axial coding was conducted. Axial coding attempts to connect each category according to the theoretical framework of causal conditions, contextual conditions, central phenomena, mediating phenomena, action/interaction strategies, and outcomes, and the axial coding resulted in the paradigm model as shown in [Fig. 4].



[Fig. 4] Paradigm Model

4.3 Optional coding

Participants in the study were recruited from people who had experience wearing VR HMDs, mostly through VR games and VR cafe experiences, indicating that VR is beginning to become a new leisure activity. Participants commonly cited “immersion in the VR effect” as a major benefit of wearing VR HMDs, and cited the discomfort of the HMDs as an intervening condition that made it difficult to consistently view VR artworks in museums.

5. Conclusion

This study proved that VR HMD-based artwork viewing provides immersion and interactivity to the viewer, but there are still a number of problems including physical problems such as headaches, dizziness, and simulator sickness, and psychological problems such as loss of reality, fear, and anxiety. Through grounded theory, this paper identified the effects of VR HMD works on different types of users.

First, based on the data obtained from the interviews with the research participants, it can be derived with the keywords to name the concepts. The 61 concepts were divided into 6 major categories and 11 subcategories.

Second, the increasing interest in VR, which is a causal condition, has led to a sense of immersion and participation due to the advantages of VR, which is a contextual condition, and this has led to the central phenomenon of VR HMD works being introduced and utilized as exhibits in museums. However, the limitations of the technology, such as the lack of functions in terms of VR technology and the inconvenience of HMDs, were identified as mediating conditions. Therefore, the function of VR was analyzed as an inconvenience for viewing artworks due to the heavy weight and strap adjustment. As a result, the respondents said that these various HMD problems could hinder the immersion, which was a big advantage.

Third, after re-analyzing the interviews, it can be identified with the two types of VR HMD users: 'conditional users' who expect the growth of VR HMDs, and 'satisfied users' who are satisfied with the current VR technology but have some shortcomings. VR experiences in museums are often one-directional with VR delivering content and information to visitors without any interaction between VR and visitors. However, the satisfied users concluded that virtual reality technology has a lot of influence on our lives, not only in museums, so there are endless possibilities for its utilization.

Based on the anaylysis, museums and VR developers can take a dual approach based on the two identified user types. For conditional users who are expecting growth in VR headset technology, being upfront about current limitations can set proper expectations, while offering future upgrades and soliciting feedback on desired features can keep them engaged as capabilities improve. For the satisfied users who see potential despite shortcomings, leveraging their optimism by showcasing VR's transformative applications across industries beyond just passive museum viewing experiences will be important.

Developing more interactive and immersive VR that allows this segment to fully explore the technology's potential is key. Universally, evolving museum VR from one-directional content delivery to experiences that enable viewer input, multi-user collaboration, gesture/voice controls, and customization options can drive participation and innovation. Applying these insights entails creating an engagement spectrum from using transparency for conditional users to tapping the enthusiasm of satisfied users, and ultimately delivering rich, dynamic VR that transcends current limitations through immersion and interactivity across novel use cases.

While this study provides valuable insights into user experiences with VR headsets in museum settings, it has some limitations. the sample size of only 8 interviewed participants is relatively small, potentially limiting the generalizability of the findings. Therefore, further study can be done with a larger and more diverse sample across different demographics could yield additional perspectives.

References

[1] H. J. Jeong, J. H. Kim, “A Study on the Application of Stereoscopic Depth Value in VR HMD”, Journal of Society for the Convergence of Humanities, Social Sciences and Technology, vol. 6, no. 4, April 2016, pp. 31-40, doi: 10.14257/AJMAHS.2016.04.16.

[2] S. H. Choi, J. S.Wonk, “The Nature of flow in virtual Reality Education: Based on A Grounded Theory Approach”, The Journal of the Korea Contents Association, vol. 17, no. 11, November 2017, pp. 446-460, doi: 10.5392/JKCA.2017.17.11.446.

[3] K. T. Kim, J. Y. Han, H. E. Lee, “A Case Study on Safety Measures for Users Experiencing the Virtual Reality - Focusing on Experiential Space for Immersive Virtual Reality -”, Journal of Korean Society of Space Design, vol. 15, no. 3, 2020, pp. 161-168, doi: 10.35216/kisd.2020.15.3.161.

[4] W. J. Jeong, G. S. Oh, S. H. Oh, “Questionnaire method for Usability Evaluation of VR Contents”, Journal of Next-generation Convergence Information Services Technology, vol. 8, no. 3, September 2019, pp. 337-350, doi: 10.29056/jncist.2019.09.11.

[5] J. Kim, “Research on VR content production through analysis of cyber sickness elements”, Journal of Next-generation Convergence Information Services Technology, vol. 10, no. 3, June 2021, pp. 231-241, doi: 10.29056/jncist.2021.06.01.

[6] K. T. Kim, H. J. Yoeb, “A case study on safety measures for users experiencing the virtual reality : focusing on experiential space for immersive virtual reality”, Journal of the Korea Institute of Spatial Design, vol. 15, no. 3, April 2020, pp. 161-168, doi: 10.35216/kisd.2020.15.3.161.

[7] G. R. Jeon, “A Study on the Visual Characteristics of the Virtual Reality Based on HMD”, The Animation Society of Korea, vol. 13, no. 1, March 2017, pp. 66-83.

[8] H. K. Shin, “The Virtual Museum and Acceptance Aesthetics of the Digital Age,” Journal of Digital Art Engineering & Multimedia, vol. 10, no. 3, September 2023, pp. 293-303, doi: 10.29056/jdaem.2023.09.02.

[9] Y. Kim, Y. H. Kim, “Examining the Impact of Online Media Advertising on Art Exhibiton Engagement and Visitor Satisfaction”, Journal of Digital Media & Culture Technology, vol. 2, no. 2, December 2022, pp. 87-97, doi: 10.29056/jdmct.2022.12.03.

[10] H. M. Tun, H. Y. Bang, “A Comprehensive Meta-analysis of the Determinants of FDI Performance in Korean Firms: Focus on Domestic Empirical Studies”, Korean Academy of International Business Management, vol. 22, no. 2, 2018, pp. 141-163.

[11] J. H. Lee, J. H. Oh, S. H. Kim, J. I. Kim, “A Qualitative Study for the Development of Design Learning Ethics Teaching Methods and Convergence Educational Contents Programs Ⅱ - Focused on student majoring in design -”, The Korean Society of Science & Art, vol. 39, no. 2, March 2021, pp. 377-393, doi: 10.17548/ksaf.2021.03.30.377.

[12] G. S. Cho, Y. G. Seo, C. H. Yu, B. B. Lee, Y. J. Kim, “Qualitative Research on the Recovery Experience of Stress in the Counselor`s Counseling Process”, The Journal of Humanities and Social Science, vol. 8, no. 2, 2017, pp. 365-386, doi: 10.22143/HSS21.8.2.20.