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The Impact of the User Characteristics of the VR Exhibition on Space Participation and Immersion

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Abstract: *With the advent of the 5G, networks and information and communication technologies have been continuously developed. In the fields of art galleries, virtual reality (VR) exhibitions that can be visited online have emerged, innovating the way of human-computer interaction and creating new artistic experiences for users. This study explores the three-dimensionality, clarity, and innovative interactions that users experience when viewing a VR exhibit, which affects the exhibit's presence. Besides, in terms of research method, the research sets spatial participation and immersion as dependent variables, with three-dimensionality (high versus low), clarity (high versus low), and innovation (high versus low) in a 2x2x2 design as the base, and explores their interaction effects. The results show that three-dimensionality and innovative interactions affect spatial participation. First of all, in groups with high innovation and low three-dimensionality, spatial participation presents a higher positive factor. Secondly, with regard to immersion, three-dimensionality, clarity and innovation present a tripartite interaction. Groups with low three-dimensionality and high clarity have a higher positive effect on immersion when the level of innovation is low. When the degree of innovation is high, the positive effect on immersion is higher in groups with high three-dimensionality and low clarity. The above results show that in the production of VR exhibitions, it is necessary to increase the three-dimensionality and clarity of exhibited image contents, while taking into account the user's perception and innovativeness. On the other hand, this study puts forward suggestions for the design, content and future development of VR exhibitions, which has important reference significance for the improvement and innovation of future VR exhibitions.*

Keywords: VR exhibition; Innovation; Space participation; Immersion; Audience characteristics

1. Introduction

As we all know, with the rapid development of digital technology and the wide application of virtual reality technology (VR), VR exhibitions that can be experienced and felt in any place have emerged.Around 2015, world-renowned museums successively launched diversified exhibitions using VR technology, made new adjustments to the content of online museums, tried virtual museum tours, and realized "remote appreciation" of collections in museums.Traditional museums with the richest collections and the most visitors, such as The British Museum in London, The Louvre in Paris, and the Vatican Museums in Rome, have also set up multimedia and digital departments. The exhibition information is synchronized with the website and APP, and transmitted through the online VR exhibition, by which, the audiences are provided with a new art appreciation experience. In particular, through the Art&Culture project, Google has built a huge online virtual museum platform, allowing users to visit and enjoy 360° VR exhibitions in famous large museums such as the Musée d'Orsay in Paris and the Museum of Modern Art in New York.

Essentially, the virtualisation of museum exhibition space and content is not a phantom, but a creative act of creating a new cultural space. Most of the online exhibitions use VR cameras to shoot existing offline exhibitions, and combine with text and images to form a VR experience. Users can actively choose real-time online exhibitions or collection of well-known art galleries at home and abroad according to their personal preferences and needs, and afterwards freely search and enjoy high-definition images of artworks. The innovation and application of this technology allows people of all classes to acquire cultural knowledge and information without barriers. It also has the function of improving artistic aesthetics and promoting cultural diffusion. Free from the limitations of time, space and physical display cost, VR exhibitions see infinite changes in content and spatial composition, which expands audiences' artistic experience in a shared way. This unique advantage deepens people's understanding of art, and at the same time continuously improves the individual's ability to appreciate art.

Furthermore, the VR exhibition has changed our appreciation of works from passive to active. For the exhibitions in the past, users can only unilaterally accept the author's intention from works exhibited. However, in the VR exhibition, users can comment through the system page, as well as share and exchange information. It guides users to an active interaction, going beyond the level of bare display. During this process, interactive effects, user experience, artistic communication and other aspects are becoming more and more important in VR exhibition design.

In addition, due to the impact of COVID-19, many important art fairs have canceled their schedules. When offline exhibitions are not possible, VR exhibitions have emerged to fill the gap. As the public's demand for culture and art increases, VR exhibitions are becoming what is expected in public culture and art that brings enjoyments. VR exhibitions have high practical value, and planning, content design, and popularization have become very important. However, at this stage, there are many design and technical problems in VR exhibitions, resulting in a decline in users' immersive experience and passion for art. At present, most of the research in related fields focuses on the level of VR technology or multimedia art exhibitions, and the research is relatively single, and there are few forms that combines VR technology with online art exhibitions. Compared with previous related researches, most researchers simply analyzed VR technology, VR exhibition characteristics and related exhibition cases, and seldom consider user characteristics or discuss future development with in-depth research conducted. With the rapid development of digital technology and continuous changes in display media, it has become the responsibility of researchers to explain this change and guide the future direction.

It is especially worth mentioning that, in terms of academic research, in Y.W.Lee (2020) study, three-dimensionality, clarity, and proximity are studied as characteristics of VR content [1]. Besides, S.S.Nam (2017) defined the characteristics of VR media as three-dimensionality, clarity and proximity, measured the level of presence and pleasure, reuse intention, and compared their differences [2]. To sum up, this study conducts an in-depth analysis of three-dimensionality and clarity as the characteristics of VR exhibitions. Besides, in the study by J.S. Lee and K.N. Lee (2018), the results showed that the more presence the user felt in VR, the higher the fun and reuse intention [3]. Based on previous research, this study focuses on presence to conduct in-depth research. Specifically, the presence is the process of experiencing the reality of the VR exhibition and being immersed in the VR exhibition.Furthermore, VR exhibition is considered as an innovative form of art exhibition, and among the characteristics of users, innovation is the tendency of users to innovate or pursue new things. M.S.Park (2017) research shows that user innovation affects the adoption of new products [4]. To sum up, this study analyzes innovation as a user characteristic of VR exhibitions.

Therefore, this paper hopes to use immersion theory to study how to improve the immersion and spatial participation of VR exhibitions by combining the characteristics of VR exhibitions with user characteristics. This will optimize the content, design and sensory immersion of the virtual environment, improve user participation and artistic experience, and enable users to better utilize and disseminate VR exhibits. The research question of this study is to explore the influence of VR exhibition characteristics and user characteristics on presence. Among them, the three-dimensionality, clarity and user's innovation of VR exhibitions are firstly studied concerning the impact on space participation, and further studies are conducted concerning the impact on immersion. Through a questionnaire survey, combined with the analysis results of SPSS software, the future development and innovation of VR exhibitions are discussed. This research can improve VR exhibitions, provide artists with reference materials for innovative genres in the field of future art creation, and provide valuable innovative guidance for the future development of VR exhibitions. In addition, it can also serve as a reference for other VR display platforms.

2. Theoretical background and literature review

2.1 VR

Virtual reality, abbreviated as VR, first appeared in the 1970s. After long-term development, it gradually began to be used in practice in the 1990s. Today, with the rapid development of computer technology, it has gradually entered the lives of modern people. 2016 is known as the "first year of virtual reality". In this year, virtual reality technology began to develop comprehensively in various fields, from tourism, games, art to shopping, medical care and real industry, etc. Virtual reality Technology has gradually penetrated into all aspects of our lives [5]. Art exhibitions actively introduce VR technology. The forms and media of exhibitions are constantly changing, resulting in a variety of content. From the static and boring exhibitions in the past, they have developed into exhibitions that can give users a dynamic experience [6]. J.H.Youn (2008) pointed out that VR technology has three-dimensional space, sensory immersion and real-time interaction. It uses computer technology to generate a simulated realistic visual experience environment through the interaction and fusion of various information, and makes users "immersed" into the environment through various sensing devices, thereby realizing information transmission and situational awareness [7]. J. H. Lee (2018) explained that VR technology makes visual, auditory, tactile, and other sensory experiences more realistic, allowing users to observe things in the space in real time as if they are on the scene, thereby expanding the content experience category [8]. VR can be divided into: Immersion VR, Desktop VR, Projection VR, Simulation VR, Tele-robotics and Third person VR according to the system environment used (Table1). VR technology is a challenging cross-technology research field, which integrates computer graphics technology, computer simulation technology, artificial intelligence, stereo display technology and other technologies, and belongs to a comprehensive integrated technology [9]. Its rise has opened up a new research field for the development of human-computer interaction interface. It has provided a new interface for the application of intelligent engineering, which has a huge impact on the information dissemination and situational perception experience in the display design environment, as well as of high research value. In the previous research, Z.Jin (2020) conducted a case analysis of museums using VR technology, and discussed the development prospects of the introduction of VR systems [10]. X.HU (2020) conducted research on the VR narrative of virtual museums, and the results showed that the use of nonlinear narrative forms can stimulate and arouse the interest of the audience, thereby achieving the purpose of paying attention to and participating in the exhibition, and the design and planning of the VR exhibition was carried out [11]. Rhee.Bo. A (2016) In the research on the appreciation of VR content of art works, the highest performance is entertainment value, but the lower the frequency of visiting the exhibition, the higher the ratio of judging the aesthetic and educational value of VR content [12]. H.J. Jang and K.H.Kim (2018) research shows that the audience's sense of presence in VR also affects content and system satisfaction [13].

Table 1. Classification of VR and its realization based on system environment

Virtual reality	Realization
Immersion VR	HMD, Data Glove
Desktop VR	Ordinary computer+LCD shutter glasses,Joystick,Mouse
Projection VR	CAVE, Holographic projection
Simulation VR	Audio-visual + Equipment (mount)
Tele-robotics	Immersion system + Robot form
Third person VR	Video camera

2.2 VR Exhibition

At present, VR exhibitions are mainly 360° panoramic or 3D virtual. It is an exhibition carried out in a computer virtual space based on online network technology and image digital technology. It is a communication method that transmits information about the object to be displayed through interaction with users. Specifically, VR exhibitions can be classified by media into various forms such as online exhibitions, digital exhibitions, and smart exhibitions [14]. Museums and art galleries in various places integrate existing digital resources at the fastest speed, and build virtual museums on the Internet through portals and mobile for clients to realize the digitization, creativity, and visualization of the content of the museum's exhibitions. Y.C.Zhang (2010) also pointed out that the production of VR exhibitions uses fish-eye cameras to take 360° pictures of the actual exhibition at multiple points. After completing the production of the above exhibited images, the process integrates the virtual exhibition scenes, with 3D display of virtual objects, two-dimensional pictures, voice explanations and other elements, and the exhibits are displayed through digital networks and media technologies [15]. The research of Y.H. Kang (2016) pointed out that the 3D modeling technology builds the 3D information of the exhibits, which is helpful for the establishment of the digital archives of the physical objects, and the users can operate them by themselves, which enhances the experience. In addition, the sense of realism and clarity brought by VR exhibitions increases the sense of immersion and expands the categories of users' spatial engagement and content experience [16].

L.T.Li (2016) stated that during the process of enjoying the VR exhibition, users can select the visiting route by clicking the system and move around freely in the virtual three-dimensional scene. By switching the screen through the guide, the user can browse the exhibition hall more conveniently. You can zoom in, zoom out, move and rotate the exhibits, and share them with social media acquaintances, which are more in line with the needs of users [17]. For example, the Web VR experience based on Oculus React VR technology jointly launched by The British Museum and Oculus produces high-resolution 360° images and various experience content. Users can open the web page and select regions, eras, and themes to browse and share according to their preferences. Y.L.Ren (2019) explained that HTML5, javascript, XML and other technologies are used to add a sense of interaction to the exhibits, where the users can click on the VR exhibit introduction or scan the QR code to watch the video commentary, pictures and information details, and conduct a comprehensive review of the exhibits, with the attributes of entertainment and education [18].H.Lun (2020) research shows that VR exhibitions have a strong sense of immersion and interactive experience with rich and complete information, and improved clarity through advanced technology can improve users' viewing experience and satisfaction [19]. Y.H.Kang (2016) believes that VR exhibitions can break the original exhibition route setting, and provide users with a variety of viewing routes, richer display content, and functions. For example, retrieval, browsing, pause, and review can be implemented on the network platform. It can well meet the needs of users for culture [16]. In addition, in the previous research, J.H.Yook (2018) analyzed 4 cases of art museums based on the characteristics of online exhibitions, proposed the most basic elements of the exhibition, designed different exhibition modes, and provided users with interesting experience [14]. Y.X.Liu (2019) studied VR images and VR museums, and extracted 10 image design elements of VR museums by analyzing the immersion, interactivity and imagination in VR to measure the needs of the audience and provide a basis for VR content design and planning [20]. Besides, Y.W. Lee (2020) studies and analyzes the impact of evaluation factors on immersion. The results showed no conscious differences between men and women in three-dimensionality, clarity, immersion, and proximity. In addition, in order to improve visual immersion, the three-dimensional modeling of people and things must be very detailed in the presentation of the virtual world, and the sense of clarity and three-dimensionality must be improved [21]. At the same time, S.U.Park (2020) explores the characteristics of user experience, centering on the VR exhibition. The results show that compared with previous VR exhibitions, the VR exhibition methods recommended by users are statistically significantly different, showing a positive impact on immersion. Research can work well for VR exhibits to provide a more immersive environment [22].

According to previous research, it can be seen that VR exhibitions have various content characteristics. This research summarizes and extracts three-dimensionality and clarity as the characteristics of VR exhibitions, and further analyzes them in combination with the research purpose of this paper.

2.3 Features of VR exhibition

2.3.1 Three-dimensionality

In previous research, it is believed that VR exhibition uses 3D stereoscopic imaging technology and special equipment to increase the sense of three-dimensionality of the screen, thereby enhancing the immersion of the content [23]. The so-called 3D stereoscopic imaging technology is to show images of different angles on each part of the left and right eyes through a system program, so that the human brain has a sense of space and feels that this is a three-dimensional image.In the 3D space, the VR exhibition undergoes rotating and scattered spatial perspective changes, which increase the visual depth, and at the same time give fish-eye effects,bringing the illusion effect of watching a large screen, and generating a more realistic picture. This can improve the three-dimensional perception, allowing the audience to experience more realistic content.In another study, Y.W. Lee

(2020) explained that the viewing space of VR exhibitions and the displayed works have a strong sense of three-dimensionality. When we appreciate the artwork in the exhibition space, it feels like seeing an object with a three-dimensional volume. In addition, the study analyzed the factors that affect immersion. The results show that the stronger the user's three-dimensionality in the 3D virtual world, the more positive the impact on immersion [17]. In addition, in the research of S.S. Nam (2017), the three-dimensional perception is used as the cognitive characteristic of 3D images, combined with the characteristics of the device, to measure the sense of presence, pleasure, and reuse intention, so as to compare the differences of VR content [24]. Moreover, H.J.Kim (2010) research results show that high-precision images can increase the realism felt by users, thereby improving presence. The perception of three-dimensionality, proximity, and clarity when using HMDs and viewing computer-generated 3D images will be factors that affect presence [25]. According to previous research, this paper defines three-dimensionality as the user's perception of "3D images of spaces and objects in VR exhibitions".

2.3.2 Clarity

In the research on the visual immersion of VR content, Y.W. Lee (2020) defines the sharpness as an index of the accuracy of the image on the screen,in other words, the freshness and clarity of the picture [17]. This is the degree to which the brightness or detail of an image can be clearly discerned through the display. Video, games, artwork and other low-definition situations will increase the user's inconvenience and affect the user's visual immersion [26]. In the presentation of the virtual world, the three-dimensional modeling of people or things must be extremely detailed. Specific to the VR exhibition, at the beginning of the VR shooting and modeling design, the color, texture and lines of the works must be clearly expressed and produced, and the space environment such as good lighting should be matched. In the process of viewing VR exhibitions, users can have the illusion that they exist in the real world, just like viewing high-definition artworks in front of their eyes. The details, texture, and style of the original artworks can be clearly presented in the VR exhibition. In another study on the use and experience of virtual reality equipment and content, J.S. Lee and K.N. Lee (2018) measured and analyzed clearness as a user's cognitive feature, and it can be confirmed that clearness and proximity have a positive impact on presence, and the higher the clarity felt in VR content, the higher the sense of presence is [3]. Lessiter et al (2001) argue that clarity is perceived as a more natural and more realistic representation, related to presence, making media systems more natural to interact with users[27]. According to previous research, this article defines clarity as "the clarity of the images in the VR exhibition space and artwork".

2.4 Presence

In VR research, presence refers to the subjective feeling that the user has forgotten the physical situation or location, but actually exists in the environment mediated by the media [28]. Presence is defined as a media-based interactive experience, just like a real experience,think of yourself as being located or existing somewhere, rather than in the real world. According to Lombard and Ditton (1997), pesence refers to the perceptual state or psychological response of users who use media as the medium. If the user realizes that the world created by the media is real and immersed in this environment, he feels like he is in the place shown by the media instead of where the user is now [28]. Witmer and Singer (1998) have the same definition of presence, and divide presence into two dimensions: involvement and immersion.Specifically, immersion was used as a shield for the real world stimulation and interference of media users in the media environment. Participation is defined as: focus on the result of a series of stimulating or meaningful activities, that is, experience [30]. In VR exhibitions, participation is more specifically divided into space and time participation, and immersion is more specifically divided into immersive dynamic feeling and immersive reality In its special exhibition on Modigliani, the British Tate Modern Museum used VR to reproduce Modigliani's studio in Paris in 1919, giving the audience the illusion of being in Modigliani's creation scene.The VR video "Dreams of Dali" was exhibited at the Dalí Art Museum. Visitors walked into Dalí's works, showing an overwhelming sense of immersion and artistic beauty. I.H.Lee (2017) research shows that the higher the clarity of VR content, the higher the spatial participation and immersion of presence [31]. This means that features such as clarity have a meaningful connection to presence.From the research of O.K.Lee and I.H.Lee (2006), it can be seen that the higher the presence, the more touching, awakening, and interesting [32]. In addition, in the study of J.S. Lee and K.N. Lee (2018), where presence was defined as the characteristics of users, the results showed that the more presence users felt in VR, the more fun and intention to reuse high [3]. In addition, the research results of Y.W. Lee (2020) show that features, such as clarity, affect the degree of presence of the picture, and a visual experience can be fully provided by improving the clarity [33]. The research of H.J.Jang and K.H.Kim (2018) shows that the user's innovativeness and immersion have a great influence on both content satisfaction and system satisfaction. VR presence, user innovation, and immersion have a significant impact on continued usage intent [13].

Based on previous research, this study defines presence as "Users feel their real existence in the virtual environment provided by VR exhibitions and interact with the situations in the virtual environment", and divide presence into "spatial participation" and "immersion" for specific measurement and analysis.

2.5 Immersion theory

Immersion theory was first proposed by Hungarian psychologist Mihaly Csikszentmihaly in 1975. Csikszentmihalyi studied how people are completely immersed in a situation when they perform certain daily activities, and found that when people perform activities, they filter out all irrelevant intuitions, i.e. enter a state of immersion.Csikszentmihalyi's definition of immersion is when people engage in a relatively challenging task that they can complete independently, and enter a common mode of experience, thereby reaching a particular state of mind. Therefore, Immersion Theory is also translated into Flow Theory or Fluency Experience. Csikszentmihalyi defines immersion as the overall experience that human beings feel by focusing their attention while performing a specific activity, which is the best experience for human beings to release the best psychological energy [34].

The application of immersion theory in exhibition design can greatly improve the user's visiting experience and interest, enrich its exhibition form and improve the exhibition effect.Furthermore, Beylefeld and Struwig (2007) used changes in sense of time, loss of self-awareness, sense of control and explicit feedback to assess immersion [35]. E.k.Ha (2010) screened the characteristics of immersive experience in media space in the research of immersion structure based on digital media space experience. Through prior research, 21 immersion factors for media space experience were extracted [36]. M.J.An (2017) focused on experiencing the exhibition content, using immersion theory to conduct research, and studying on allow users to directly move their bodies to interact with the works, so as to gain sensual experience. Research has shown that immersion is achieved when self-engagement is high and when self-reactions are given immediate feedback [37]. This research is combined with immersion theory, that is to say, by using VR exhibitions, appreciating art works, actively participating and interacting, users can obtain great artistic experience and interest, fully immersed in the visiting activities, and achieve the best psychological state.

2.6 User characteristics of VR exhibitions

2.6.1 Innovation

Rogers (1995) defines innovation as "a new idea, practice or thing considered by an individual or other accepting unit" [38]. In the research of J.H.Jeon (2002), innovation is defined as the individual differences in the willingness or inclination to accept new things [39]. E.J.Pyeon and B.H.Park (2005) explained that an organization or individual accepts new ideas relatively quickly, and the more innovative, the higher the preference for new ideas [40]. According to previous research, the concept of innovation related to the acceptance of information technology can be defined as the willingness of individuals to try to accept new information technologies and the level of positiveness shown in the process of accepting innovative technologies [41]. In the research by S.J.Park and J.W.Lee (2018), innovation is regarded as the tendency of users to hope to innovate or pursue new things. Users should have certain degree of creativity to form new perceptions, appreciation concepts and operating methods, and new cognitive habits, and go to adopt VR exhibition application [42]. J, W.C.Arts (2011) and others have studied that user innovation has a positive impact on innovative adoption behavior [43]. Manzano (2009) and others confirmed that user innovation becomes the acceleration of the introduction of new technologies [44]. Research by Venkatesh et al (2003) also shows that user innovation affects the adoption of new products, as well as the introduction of new products [45]. In addition, the research of S. H. Kim and J. Y. Kang (2005) shows that the higher the innovation, the higher the tendency to pursue participation, experience and convenience, and the situation of obtaining information scattered through various media has been confirmed [46]. J.Y.Na and M.Y. Wui (2019) mentions that highly innovative people form more positive perceptions in terms of participation and ease of use, and thus show higher utilization intentions for new information technologies or systems [47]. This study defines innovation as "the degree of positive acceptance and attention to new technologies by users who have experienced VR exhibitions".

This study can predict that the characteristics and user characteristics of VR exhibitions will affect spatial participation and immersion. According to previous research, this research has set the assumption that there is an interactive effect of three-dimensionality, clarity, and innovation.

H1: The interaction between three-dimensionality, clarity, and innovation will affect spatial participation.
H1-1: Three-dimensionality, clarity, and innovation will interact with space participation.

Secondly, from the perspective of the overall impact of the independent variables proposed in Hypothesis 1 on spatial participation, the user's perception of immersion in a VR exhibition is further explored. Therefore, in view of the interactive effect of independent variables on immersion, the following hypotheses are proposed.

H2: The interaction between three-dimensionality, clarity, and innovation has an impact on immersion.
H2-1: Three-dimensionality, clarity, and innovation interact with immersion.

3. Materials and Methods

3.1 Research design

Aiming at the research purpose of the VR exhibition, this research will adopt a combination of literature research method and empirical research method. Firstly, through literature research, the research will clarify the definition and current situation of VR exhibition applications, and introduce the characteristics and applications of VR exhibitions in detail. The research explains in detail the concept of presence and the user characteristics of the VR exhibition. Secondly, the empirical research will develop a questionnaire based on literature research, using the Internet questionnaire survey platform "WenJuanXing" to distribute questionnaires to users of Chinese VR exhibitions, and finally use SPSS 21.0 to conduct empirical analysis.

Specifically, this survey studies users who attend VR exhibitions. The effective questionnaire survey age group collected was probably concentratedin the 30-40 years old. The first part of the questionnaire is about demographics, with four questions in total, asking about gender, age, education and occupation. The second part of the questionnaire is the main variable question. A survey of 6 questions was conducted on the three-dimensional VR exhibition,in addition, 3 questions are about clarity, 8 questions for presence, and 9 innovative questions. The questionnaire survey was conducted using a 5-point measurement method.In order to facilitate the direct visit of survey users, the viewing URL of the VR exhibition was written at the top of the questionnaire. The questionnaire was conducted from July 7, 2021 to July 18, 2021. Among the 240 questionnaires recovered, 206 valid questionnaires were selected as the analysis object, and the other 34 were missing or false.

Table 2. VR exhibition user characteristics measurement project

User characteristics	Measuring project	Reference
Three-dimensionality	*1.In the VR exhibition, the artwork is very three-dimensional.* *2.In the VR exhibition, I think the distinction between background and artwork is very clear.* *3.In the VR exhibition, feel the artwork at easy reach.* *4.Watch the VR exhibition and feel like the artwork is really on display.* *5.Watching the VR exhibition, the exhibits seem to walk by.* *6.Watching the VR exhibition I think something has popped out.*	I.H.Lee (2017)[31] S.S. Nam, H.S .Yu, D.H. Shin (2017)[24]
Clarity	*1.The quality of the artwork presented in the VR exhibition is very clear.* *2.The resolution of the pictures presented in the VR exhibition is high.* *3.The color of the artwork presented in the VR exhibition is clear.*	I.H.Lee (2017)[31]
	1.spatial participation: *1.I feel that the exhibits are like being exhibited in front of my eyes.* *2.It feels like moving in the background of a VR exhibition.* *3.It feels like experiencing a new virtual world.*	S.S.Nam,

Presence	*2.Immersion*	*1.I feel that the VR exhibition is real.* *2.I feel like I'm looking at artworks in the exhibition hall.* *3.I feel that I also participated in the exhibition.* *4.I feel that the VR exhibition screen exists in real life.* *5.VR exhibition works can bring a multi-sensory immersive experience.*	H.S .Yu, D.H. Shin (2017)[24] I.H.Lee (2017)[31] H.J. Jung, and J.E.Yoon (2017)[48]
Innovation	*1. Be open to new technologies and technological innovation.* *2.I like to try novel things.* *3.I try new things earlier than the people around me.* *4.I like to try some new ways to do something.* *5.When new technologies appear, I will be a member of the first group that has been used.* *6.I am more willing to know the latest information.*		Thomas Leicht，Anis Chtourou，Kamel Ben Youssef (2018)[49] M.W.Choi (2011)[50]

4. Results

4.1 Characteristics of samples

From the perspective of the gender composition of VR exhibition users, the sample is 106 males (51.46%) and 100 females (48.54%). From the perspective of age distribution, the number of people between 30 and 39 years old is 53 (25.73%). Classified by academic qualifications, 75 people (36.41%) graduates from high school, 49 people graduates from junior college (23.79%), 60 people graduates from university (29.13%), and 22 people graduates from graduate school (10.68%). Among them, the number of people who graduates from high school has the highest proportion. In terms of the equipment used to attend VR exhibitions, 55 people (26.7%) use smartphones, 63 people (30.58%) use PCs, 53 people (25.73%) use tablets, and 35 people (16.99%) use laptops.

Table 3: Characteristics of samples

		Frequency	**The percentage（%）**
Gender	*Male*	106	51.46%
	Female	100	48.54%
Age	*At the age of 20 to 29*	42	20.39%
	30 to 40	53	25.73%
	41-49 years old	52	25.24%
	50-60 years old	37	17.96%
	More than60 years old	22	10.68%
Record of formal schooling	*Under the high school*	75	36.41%
	College	49	23.79%
	Undergraduate	60	29.13%
	Master	22	10.68%
Watch the VR exhibition using equipment	*Smart phone*	55	26.7%
	PC	63	30.58%
	Tablet pc	53	25.73%
	Laptop	35	16.99%
	Other	0	0%
Total		206	100%

4.2 Reliability analysis

In order to measure the feasibility and reliability of the project, this study adopts exploratory factor analysis and principal component analysis. The variables are independent of each other to simplify variable positioning. The extraction can judge the lateral items at the same time with a fixed value of 1.0, the results are presented in Table 4 and Table 5. The factor overload values of all the measurement items shown in this study are all higher than 0.5, and the KMO value is greater than 0.7, the numerical value is presented 0.905, ensuring the feasibility of concentration. In order to investigate the internal consistency of the measurement variables used in this study, a reliability analysis was carried out through Cronbach'sα value, the results showed that the three-dimensional perception was 0.936, the clarity was 0.802, the spatial participation was 0.862, the immersion was 0.921, the innovation was 0.9, and each factor all exceeding the standard value are greater than 0.8, and the reliability is good. Therefore, the overall reliability of the constituent concept of this research is at an acceptable level, which ensures the feasibility of the research.

Table4: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.905
Bartlett's Test of Sphericity	Approx. Chi-Square	3184.907
	df	231
	Sig.	0.000

Table 5: Reliability analysis

Factors		Factor loading	Extraction	Eigenvalue	%of Variance	Cronbach a
Three-dimensional	1	0.851	0.753	4.593	20.877	0.936
	2	0.838	0.749			
	3	0.856	0.768			
	4	0.868	0.780			
	5	0.838	0.745			
	6	0.871	0.797			
Clarity	1	0.862	0.837	4.474	20.339	0.802
	2	0.838	0.829			
Spatial participation	1	0.842	0.790	3.846	17.484	0.862
	2	0.851	0.793			
	3	0.834	0.775			
Immersion	1	0.845	0.837	2.388	10.855	0.921
	2	0.837	0.829			
	3	0.851	0.779			
	4	0.831	0.733			
	5	0.836	0.728			
Innovation	1	0.827	0.779	1.616	7.344	0.930
	2	0.842	0.733			
	3	0.827	0.728			
	4	0.795	0.713			
	5	0.859	0.767			
	6	0.853	0.767			

4.3 Correlations analysis

In order to study the hypothesis proposed in this study, the correlations analysis of the variables of three-dimensional, clarity, spatial participation, immersion and innovation is carried out. The results are shown in Table 6. When the Pearson correlation coefficient is between 0.2-0.4, the correlation is low, the correlations between 0.4-0.7 is relatively high, the correlations between 0.7-0.9 is relatively high, and the correlations between 0.9-0.9 is relatively high. Therefore, all variables are directly related.

Table 6: Correlations analysis

Factors	1	2	3	4	5
Three-dimensional	1				
Clarity	.258**	1			
Spatial participation	.276**	.380**	1		
Immersion	.268**	.372**	.327**	1	
Innovation	.246**	.327**	.340**	.353**	1

4.4 Descriptive statistics of variables and group variables

In order to test the hypothesis of this study, the independent variables were divided into high and low group groups, and the sample groups were more appropriately divided based on the mean value. Therefore, groups were grouped according to their respective mean values, coded and analyzed (Table 7). Specifically, the average value is: 3.8738 three-dimensional, 3.8665 clarity, and 3.8511 innovation. Based on the assumptions of this study, the design is 2x2x2 in terms of three-dimensionality (high vs. low), clarity (high vs. low) and innovation (high vs. low).

Table 7: Characteristics of independent variables

Factors	Collective	Factor value description	N
Three-dimensional	1.000	*Low Three-dimensional*	43
	2.000	*High Three-dimensional*	163
Clarity	1.000	*Low clarity*	50
	2.000	*High clarity*	156
Innovation	1.000	*Low Innovation*	52
	2.000	*High Innovation*	154

Research hypothesis 1-1 is that "three-dimensionality, clarity, and innovation interact with spatial participation". In order to verify the hypothesis, an ANOVA analysis was carried out (Table 8), and the influence of each independent variable on the dependent variable and the interaction between the variables were analyzed.In the analysis, spatial participation was set as a subordinate variable, and the results showed that the main effect appeared in the sense of clarity ($F= 8.396$, $p<0.05$) and innovation ($F= 20.773$, $p<0.05$). Specifically, the high clarity group ($M=3.800$) was higher than the low clarity group ($M=3.222$), and the high innovation group ($M=3.965$) was higher than the low innovation group ($M=3.057$).

Moreover, the interaction between the variables related to spatial participation was analyzed, and the results showed that the result value of the interaction between three-dimensional perception and innovation was $p<0.05$ level ($F=4.629$, $p=.0.033$), which can be seen as a combination of three-dimensionality and innovation, it has a positive impact on the dependent variable.It can be seen from Figure 1 that among the groups with high innovation and low three-dimensional perception, the positive influence on spatial participation is higher. In addition, the significant probability of the interaction between clarity and innovation is $p=.0.056$. This can be explained as the combination of clarity and innovation, which has no effect on the dependent variables, but with guiding significance. In other words, among the groups with a higher number of people with a sense of clarity, the more innovative they are, the more conservative their spatial participation will be.

Table 8. Spatial participation, Three-dimensionality, Clarity, and innovative ANOVA results

Dependent Variable	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Spatial participation	*Corrected Model*	48.528a	7	6.933	7.247	0.000
	Intercept	1187.231	1	1187.231	1241.116	0.000
	Three-dimensional low and high	3.108	1	3.108	3.249	0.073

	Clarity low and high	8.031	1	8.031	8.396	0.004
	Innovation low and high	19.871	1	19.871	20.773	0.000
	*Three-dimensional low and high * Clarity low and high*	0.452	1	0.452	0.473	0.492
	*Three-dimensional low and high * Innovation low and high*	4.428	1	4.428	4.629	0.033
	*Clarity low and high * Innovation low and high*	3.536	1	3.536	3.696	0.056
	*Three-dimensional low and high * Clarity low and high * Innovation low and high*	0.070	1	0.070	0.073	0.787
	Error	189.403	198	0.957		
	Total	3277.778	206			
	Corrected Total	237.931	205			

a.R Squared=0.204(Adjusted R Squared =0.176)

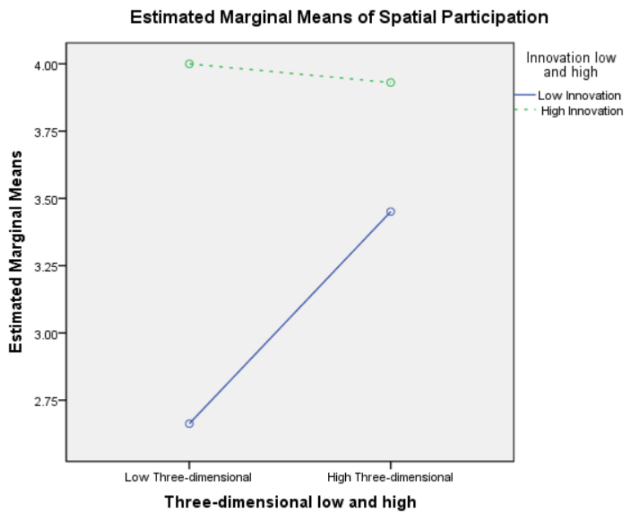

Figure 1. Three-dimensional and innovative interactive effects

Hypothesis 2-1 "Three-dimensionality, clarity, and innovation interact with immersion".In order to verify the hypothesis, the research was carried out (Table 9), and the results showed that there was a main effect of clarity (F=21.094, p<0.01) and innovation (F=14.239, p<0.1)(Figure1)**.** Specifically, there are more high-definition groups (M=3.993) than low-definition groups (M=3.125). Compared with the less innovative group (M=3.202), the more innovative group (M=3.916) has higher positive factors for immersion.

The interaction between the variables of immersion is analyzed, and the result shows that the result value of the interaction between clarity and innovation is at the p<0.05 level (F=23.683, p=0), which can be regarded as the combination of clarity and innovation has a positive impact on immersion.It can be seen from Figure 2 that the higher the sense of clarity, the lower the level of innovation and the higher the sense of immersion.In addition, the sense of three-dimensionality, interaction and innovation have a three-dimensional interaction on the immersion of subordinate variables.It can be seen from Figure 3 that when the innovation is low, the positive impact on immersion is higher in groups with low three-dimensional perception and high clarity. That is to say, the clearer the VR display is, the stronger sense of immersion the audience's will have. When the innovation is on high level, the positive impact on sense of immersion will be high in groups with high three-dimensional perception and low clarity. This means that among highly innovative audiences, the higher the three-dimensional perception when attending VR exhibition, the more immersive it can be.

Table 9. Immersion, Three-dimensionality, Clarity, and innovative ANOVA results

Dependent Variable	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Immersion	*Corrected Model*	69.819a	7	9.974	11.591	0.000
	Intercept	1220.010	1	1220.010	1417.814	0.000
	Three-dimensional low and high	2.512	1	2.512	2.920	0.089
	Clarity low and high	18.151	1	18.151	21.094	0.000
	Innovation low and high	12.252	1	12.252	14.239	0.000
	*Three-dimensional low and high * Clarity low and high*	1.632	1	1.632	1.896	0.170
	*Three-dimensional low and high * Innovation low and high*	0.081	1	0.081	0.094	0.759
	*Clarity low and high * Innovation low and high*	20.379	1	20.379	23.683	0.000
	*Three-dimensional low and high * Clarity low and high *Innovation low and high*	4.702	1	4.702	5.465	0.020
	Error	170.376	198	0.860		
	Total	3294.400	206			
	Corrected Total	240.195	205			

a.R Squared=0.291(Adjusted R Squared =0.266)

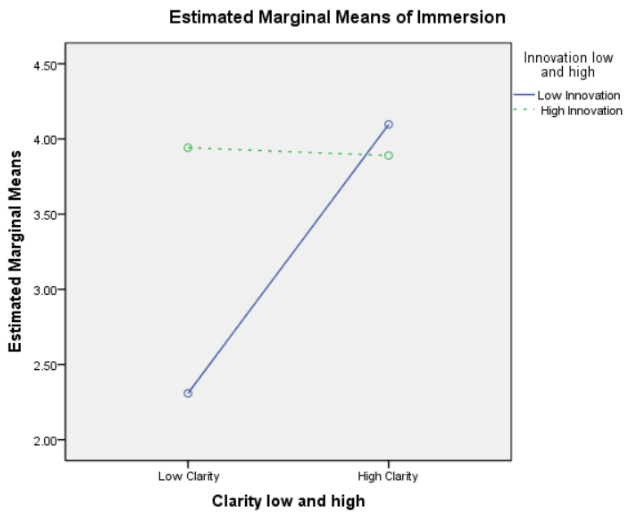

Figure 2. Arity and innovative interactive effects

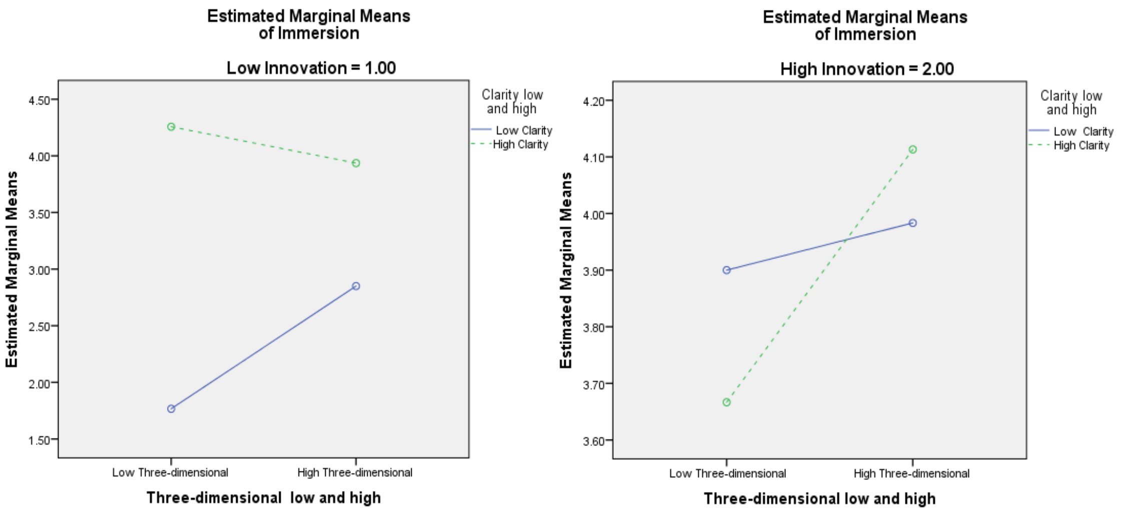

Figure 3. Three-dimensionality, clarity and innovative interactive effects

5. Discussion and Conclusions

This research explores the interactive effects of three-dimensionality, clarity, and innovation in VR exhibitions on spatial participation and immersion. The research results show that, first of all, in terms of clarity, the high-clarity group is higher than the low-clarity group, and the innovation is higher; and when compared with the less innovative groups, its positive factors for spatial participation are higher. In terms of interaction, the combination of three-dimensionality and innovation has had a positive impact on the dependent variable. Among the groups with high innovation and low three-dimensional perception, spatial participation presents a higher positive factors.Besides, combination of clarity and innovation, which has no effect on the dependent variables, has guiding significance. In other words, among the groups with a higher number of people with a sense of clarity, the more innovative they are, the more conservative their spatial participation will be. Secondly, there are more high-clarity groups than low-clarity groups. Compared with the less innovative group, the more innovative group has higher positive factors for immersion. The interaction between the variables of immersion is analyzed, and the result shows that the result value of the interaction between clarity and innovation, which can be regarded as the combination of clarity and innovation has a positive impact on immersion. The higher the sense of clarity, the lower the level of innovation and the higher the sense of immersion. In addition, the sense of three-dimensionality, interaction and innovation have a three-dimensional interaction on the immersion of subordinate variables. When the innovation is low, the positive impact on immersion is higher in groups with low three-dimensional perception and high clarity. That is to say, the clearer the VR exhibition, the more immersive the audience will be. When the innovation is on high level, the positive impact on sense of immersion will be high in groups with high three-dimensional perception and low clarity. This means that among highly innovative users, the higher the three-dimensional perception when viewing a VR exhibition, the more immersive it will be.

This research focuses first on the impact of the user's perception of clarity on space participation in VR exhibitions, and it has a positive impact on space participation in groups with a high clarity.In addition, the positive factors for immersion are higher in groups with high clarity. Clarity increases the user’s artistic experience,therefore, it is very necessary to improve the quality of the hardware equipment for VR shooting in the future, which can effectively increase the clarity of the imaging of art works, especially in dynamic images, complex graphics, special scenes (such as night), etc., as well as increase the image accuracy of recognition. On the other hand, in the production process of VR display content, the display screen can be set to a large scale, highlighting the detailed local performance effects of artistic works such as points, lines, surfaces, colors, textures, and scene lights.In addition, with the development and promotion of 5G networks, VR technology will be effectively improved. Because 5G technology has the advantages of high bandwidth, low latency, and high coverage, it can realize high-speed, high-efficiency, and high-definition VR information transmission. The data processing speed will be greatly improved, as 5G can transmit high-quality 4K or even 8K high-definition images, reduce VR dizziness, break through the previous limitations, create a clearer virtual environment, and increase the user's immersive experience.

This research also pays attention to the impact of user innovation and three-dimensional perception. From the research, we can see that among highly innovative audiences, the higher the three-dimensional perception when watching VR displays, the more immersive they will be. In the design of VR display content, more in-depth visual differences, scene rendering, the production of depth of field, and 3D layout of artworks will effectively enhance the three-dimensionality. In the future, VR exhibitions should pay more attention to shaping the sense of space, focusing on changes in spatial perspective, highlighting the shape, location, and three-dimensionality of the exhibits, thereby increasing the visual depth. The lighting settings in the exhibition space should also be adjusted according to the appropriate brightness, wavelength, and chromaticity to create the true state of the exhibits and create a three-dimensional, realistic visual perception.

In the future development of VR exhibitions, it is also necessary to understand the characteristics of the display platform, activate the interactive functions of the online display platform, diversify the standards developed by visitors, and actively introduce and utilize new technologies. The design of the VR exhibition hall needs to be artistic, and improving the appreciation experience and highlighting the theme and design style of the exhibition are the primary principles of the exhibition hall design.

The research value of this article is to analyze the impact of the characteristics of VR exhibitions and user characteristics on presence. The results show that the clarity and three-dimensionality of the VR exhibition content perceived by the user affects the immersion and spatial participation. And from the professional angle of art, the research proposes measures and methods for the improvement and perfection of VR exhibitions, thereby improving the user's artistic experience, which has important guiding significance for the future design and development of VR exhibitions. It also provides a valuable reference for other VR exhibition platforms. In terms of academic value, this research helps to enrich and improve the theory of immersion.

The limitation of this research is that it has not analyzed the shortcomings and limitations of VR exhibitions. In future research, this should be included in a more comprehensive analysis. The VR exhibition case is too little, therefore, more targeted VR exhibition cases should be analyzed in future research. In addition, further research should be conducted on the continued use intentions of VR exhibition user's in the future.

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