Dream VR: an Autobiographical Design Research on Curating a Socially Engaging and Informative Virtual Exhibition in Social VR

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Fig. 1. Users appreciate digital artworks in VRChat

Fig. 2. Users visit an art exhibition together in VRChat

Virtual exhibitions have long been regarded as an extension of information delivery for physical exhibitions. However, what can virtual exhibitions offer as a novel experience independent from physical exhibitions is still largely unexplored. In this study, we investigate the promises and challenges to experience exhibitions in VR. Drawing from experts' insights, we summarize a set of design guidelines on what design choices in physical exhibitions can be considered in virtual exhibitions and what adaptations need to be made when curating virtually. Then, using an autobiographical approach, we curated a virtual exhibition in VRChat with the insights gained from interviews. Our exhibition aims to validate the design guidelines drawn from expert interviews with audiences. The results show that our approach of curating a virtual exhibition in VRChat has made audiences engaged with the exhibits and gain novel insights on virtual exhibitions.

CCS Concepts: • **Human-centered computing** → **HCI design and evaluation methods**.

Additional Key Words and Phrases: Virtual Exhibition, Virtual Museum, Visitor Experience, Implementation, Interivew, User Survey

1 INTRODUCTION

Virtual exhibitions refer to content-based exhibitions that are held online in various digital forms in the field of arts, technology, and cultural heritage, etc. Virtual exhibitions have long been regarded as an extensional information delivery platform for physical exhibitions [46]. However, after experiencing the aftermath of COVID-19 pandemic, during which physical exhibitions have been frequently canceled, virtual exhibitions have become a common and significant back-up plan to highlight its learning values and provide museum experience. In recent HCI research agenda,

virtual exhibitions have been envisioned as virtual places that provide access to structured museum narratives and immersive experiences [39]. For audiences, a digital exhibition experience should not be inferior, less authentic or a substitute to a physical experience– it is simply a different experience [23]. However, currently there are very few developments in the exhibition design guidelines and curatorial strategies investigating how to make virtual exhibitions as a novel experience independent of physical exhibitions.

Prior research on virtual exhibitions has mainly focused on semantic web page showcase as an alternative information acquisition method [46], and existing digital curatorial practices on media artworks that are process-oriented or immaterial (i.e., only software), or networked systems [36]. This primarily poses a question to the proper selection of exhibition medium among a wide variety of potential virtual exhibition instantiations delivered through multiple platforms and technologies (e.g. the semantic web, VR, AR, etc.). However, except for the commonly developed form of web-based virtual exhibitions, there's a lack of exploration via the technology of virtual reality (VR), which directly originates from a computer-simulated 3D virtual environment with the characteristics of immersion and embodiment dedicated to providing an immersive user experience.

Additionally, there has been an emerging trend growing from physical museum institutions that museums have gradually become shared spaces with various audience communities - local, national and global, and move from collection-centered to user-/visitor-centered institutions [23]. Socialization thus has become an important factor in museum management that allows visitors to share the experience with others, thereby increasing the visibility of the museum and its "social" rating [23]. However, there's still a lack of socialization among the online multi-user communities in current virtual exhibition practices, whose values and effects are under exploration and become the major motivation of our research.

Our research goals mainly lie in the following three aspects. First, we intend to learn from physical curation and gain design insights for virtual curation strategies. Second, we want to explore a novel exhibition curatorial approach independent of traditional physical exhibitions, which is affordable to provide immersive and interactive virtual exhibition experiences. Last, the exhibition approach should also combine an immersive, embodied experience afforded by VR technology and multi-user socialization among certain online communities. Specifically, we report our findings and design implications to explore the following research questions in this paper:

- **RQ1:** What are some promises and challenges for audiences to experience exhibitions in VR, compared with exhibitions in real life?
- **RQ2:** How to conquer the challenges that the current virtual exhibitions are faced with?
- **RQ3:** What design strategies are effective to engage audiences in experiencing and acquiring information about virtual exhibitions?

To better understand the sociotechnical phenomenon of VR exhibitions and its genre-and community-specifc promises and challenges from an expert's perspective, we first conducted an interview-based study with 8 groups of professional art curators (13 participants in total) as experts in the field of curatorial practice. The interviews reveal promises and challenges of virtual exhibitions. Informed by our expert interviewees about various characteristics of virtual exhibitions and potential design strategies, with an autobiographical approach, we curated a novel VR exhibition, which combines an immersive, embodied experience afforded by VR technology and multiuser socialization via a popular social VR platform - VRChat [1]. The exhibition aims to validate the design guidelines drawn from expert interviews. The results show that our approach of curating a virtual exhibition in social VR has made audiences engaged with the exhibits and gain novel insights on virtual exhibitions.

Thus, contributions of our research in the field of HCI are: i) presenting industry strategies about virtual exhibition design and curatorial strategies from expert interviews. ii) proposing the prototype of a novel VR exhibition independent of traditional physical exhibitions, which combines an immersive, embodied experience afforded by VR technology and multi-user socialization via social VR platform. iii) validating the strategies provided by experts from the interviews in the user study and providing design insights for future virtual exhibition design.

2 RELATED WORK

In this section, we investigate research into virtual museums and exhibitions, followed by a review of virtual curatorial approaches. Lastly, we examine existing social VR platforms and the social characteristics of them.

2.1 Virtual Museums and Exhibitions

2.1.1 Virtual Museums. Andrews and Schweibenz firstly defined "virtual museum" (VM) as "a logically related collection of digital objects composed in a variety of media which, because of its capacity to provide connectedness and various points of access, lends itself to transcending traditional methods of communicating and interacting with visitors [9]." Even though the concept of virtual museums is still young [39], it has been extensively studied by scholars from different fields, while the targeted medium changes from CD-ROM, the World Wide Web, and mobile applications to VR and augmented reality [24].

Previous studies on virtual museums have mainly focused on technological development and user experience design which could support the establishment of VMs, including digital collection dataset, navigation, spatial design, etc. According to Takahashi et al., nowadays users can easily access to the cultural heritage stored in museums around the world, search and access virtual museums information as the contents of single federated museums [41]. Caputo et al. examined a novel navigation technique based on locomotion control in VMs, where the user selects the travel destination looking from a different point of view in order to increase context information [28]. More recent research from Wolf's team compared UX in the Otto Weidt Museum for the Blind physically, with the experience in its virtual replica, and investigated different strategies in designing the media, content, and interactivity in a VM environment [45].

Moreover, with the rapid development of the internet and ubiquitous computing, we have seen highly successful attempts in using VR as part of the museum experience to highlight the importance of cultural heritages in people's daily lives [22]. Most of the experiences, however, was designed to be used inside the museum as part of the physical exhibition [24]. However, using VR to provide "off-site" visiting experiences is still unexplored. Recently, Giangreco et al. developed the VIRTUE system - a generic, customizable VR system in which curators can easily create multi-modal, virtual 3D exhibitions where visitors can navigate to enjoy the exhibits [20].

2.1.2 Virtual Exhibitions. Virtual exhibitions (VEs) refer to content-based exhibitions in the field of arts, technology, and cultural heritage, etc., which are held online in various digital forms. Virtual exhibitions would usually be visualized as standard web contents or web-based VR/AR presentations displayed in an integrated end-user interface [23]. Visitors can use the former to simply search and browse the database contents and the latter to examine and manipulate virtual reconstructions of selected objects in 3D environments. Virtual exhibitions must provide museum visitors with an intuitive human-computer interface, so that users should be able to interact with digital contents as easily and naturally as they can in real-world scenarios [27].

A majority of prior research about virtual exhibitions put the emphasis on how to construct narratives and create an immersive environment in VE practices. In the field of cultural heritage digital archiving, various narrative models

have been developed to enhance the information contents and functionality in virtual environments [23]. For example, in the Personalizing Access to Cultural Heritage Spaces (PATHS) project, a system that allows visitors to act as an interactive personalized tour guide through existing digital collections was created [18]. In addition, O'hOisin et al. designed a multimedia VE experience involving and examining visitors' interactive behaviors blending video, audio, and interactive technologies [34].

When specifically focusing on VEs in the medium of VR, there are usually VR exhibitions investigating design guidelines and strategies about shaping user experience, information acquisition, and providing a sense of immersion in 3D simulated environment. A recent study called Viking VR explores the design of informative and compelling VR experiences and issues surrounding interaction design for the long-term deployment of VR exhibitions [38]. What's more, there have always been projects such as ChroniclesVR's work for the Waterford Viking Triangle [7], the Virtual Dutch Men's EUseum [43] project, etc. reconstructing scenes from the past or to enable viewers to access reconstructed galleries remotely and at their own pace via high resolution HMDs.

2.2 Virtual Curatorial Approaches

In recent decades, as museums have evolved into cultural incubators relying on emerging technology to enhance the presentation and curation of collections, the rapid growth of digital media has had a tremendous impact on the work of curators. Early exploration of digital art curation started around the 1960s. At that time, the issue sought to consider media artworks that are process-oriented or immaterial (for example, only software), or networked systems and how they exist in gallery collecting processes and preserving of media art [36].

Prior curatorial research and practices focus on the presentation and mediation of digital culture and the new art forms in the information age [21]. In the project MOVIO, the research team designed a toolkit for creating curated digital exhibitions, which enabled all public or private institutions to easily create and publish cultural narrations with personalized paths and providing access to local cultural resources [31]. Additionally, the ARCO project instead takes a multimedia approach by creating virtual representations of artifacts and permits interaction with various digital surrogates [35]. Also, in contemporary art curation, the project "New Scenario" founded by artists Paul Barsch and Tilman Hornig is a representative work of an experimental method that shapes the staging of curated artworks in the online presentation [37].

Nowadays, after experiencing the aftermath of COVID-19 pandemic, many art professionals pointed out the importance of using digital technologies to create "new forms of viewer participation" [13], "deliver interaction, communication and connection" [32], and "provide a way of coming together" [44]. However, many of these art critics also noted that doing this would not be an easy feat for art institutions, as many had little experience with creating a sense of connection by non-physical means. In the attempts to reshape virtual exhibition experiences, art curators must look into emerging technologies such as VR and augmented reality (AR) for experimenting virtual curatorial practices [40]. For example, the VR medium can provide visitors with immersion and embodiment [42], indicating the huge potential for audiences to appreciate artworks through VR. However, most applications of VR in museum settings are affiliated with physical exhibitions [38], and how VR exhibitions as an individual novel experience are largely unexplored.

2.3 Social VR and Socialization in Exhibitions

Social VR represents a growing set of mult-iuser applications that enable people to interact with one another in virtual space through VR head-mounted displays (HMDs) [29] [17]. Commercially available applications include VRChat, AltspaceVR, High Fidelity, Mozilla Hubs, etc. As part of a diverse and rapidly evolving media ecology, social VR

ID	Gender	Age	Working Experience (Years)	Curation Genre
E1	Female	27	3	Hybrid
E2	Male	28	2	Virtual
E3	Female	32	5	Hybrid
E4	Male, Female	26, 26	3	Hybrid
E5	Female	39	18	Physical
E6	Female	30	8	Hybrid
E7	Male	40	7	Hybrid
E8	Male	41	20	Physical

Table 1. Demographic Information of Expert Interviews

applications vary widely in terms of purposes, aesthetics, themes, functionality, interaction mechanics, and emergent social norms [29]. Accordingly, each application reflects a different answer to the question of what it means to be social in a VR environment [30]. Similar to traditional 2D social media forms on the web, different platforms prioritize different dimensions of sociality and reflect different design approaches to social interaction [29].

While there is a large body of prior work, none has investigated its application in museum and exhibition settings. Noteworthily, there is a trend for museums and exhibitions to become a social occasion as visitors' experiences can be enriched by sharing with other visitors [23]. Social experiences can enhance audiences' information acquisition [12] and thus should be valued in exhibition settings since one of the affordances that exhibitions provide is education value. Investigating whether and how enriching social experiences in virtual exhibition can enhance audiences' engagement and information acquisition can better excavate the value of social VR.

3 STUDY 1: EXPERT INTERVIEWS

3.1 Methods

To understand what differences lie in the systematic framework of virtual curation compared with the curation of a physical exhibition, and what effective strategies that curators usually take to engage audiences within the virtual environment, we conducted a qualitative interview-based study with 8 groups of professional art curators (9 participants in total) as experts in the field of curatorial practice and exhibition experience.

3.1.1 Participants. All the curators who attended the interviews must have been curating physical exhibitions in authoritative art institutions around the world for more than 3 years, or have at least 1 year's experience of working with a virtual curatorial medium (see Table 1). The selection of curators with comprehensive backgrounds ensures that this interview can not only highlight the unique advantages of virtual exhibitions on the premise of comparing with physical exhibitions, but also reveal the original problems and challenges of the virtual curation industry in its initial stage.

Because art curators mostly work as independent curators or sometimes accept work opportunities commissioned by art museums and galleries, potential professional curators were purposefully approached through either personal connections or sending an inviting email to the official account of relevant art institutions to reach out their cooperated curators. Four groups of interviewees were contacted via authors' personal connections to them, and were invited to participate through direct messaging on Instagram and WeChat. Another 3 groups of interviewees were recruited via the inviting email to their affiliated institutions. The other group of curators used to be an artist group who participated in the artwork collection of the VR exhibition that we designed. During the communication process via emails, we found

that they held strong expertise in virtual curation and virtual museum experiences. Therefore, we also invited them to become one of our interviewees. We distributed recruitment advertisements in Chinese and English through private messages on WeChat, Instagram, or e-mail, soliciting those who wanted to participate to contact the research team back. All those who self-identified as professional art curators with at least 3 years of physical curation experiences with various art institutions, or with at least 1 year of virtual curatorial practices were invited to participate. Since this study valued the individual experiences as curators, and there is no previous work exploring this specific definition or categorization of virtual curation work, purposive sampling was helpful to explore factors that could influence curators' perceptions.

3.1.2 Interview Protocol. Semi-structured interviews were conducted with 8 groups of professional art curators. The interviews were conducted remotely using video or audio calls in July and August of 2022 via Zoom and Tencent Meeting. Each interview lasted approximately 60 minutes. The interviews included questions about the curator's working experiences, their own workflow of curating either physical or virtual exhibitions, preferred strategies to engage and educate audiences, and so on. Interviewees were asked specifically about the differences that lie in the process of designing physical and virtual exhibition experiences from a curator's perspective, including different artwork medium selection, information acquisition methods, and audience engagement strategies. What's more, they were also primed to think about their first-hand experiences when navigating various virtual exhibitions on the market nowadays as a visitor on their own - what advantages and drawbacks that current virtual exhibitions have, what promises and challenges that audiences tend to perceive in their visits to virtual exhibitions, and what evolutionary changes that they expect to see in the future development of virtual exhibitions further, etc. Interviews were conducted in Mandarin and English, audio-taped, and transcribed by the inserted transcription service of Zoom and Tencent Meeting after removing all personally identifiable information.

3.1.3 Data Analysis. The interview transcripts were analyzed using an open coding method. Three native Mandarin-speaking authors coded the transcripts individually using an inductive approach and met to discuss disagreements to gain consensus about codes. All the codes were then translated into English and were discussed by the research team using affinity diagramming to find emerging themes. All codes were transcribed on an independent codebook and then arranged in a random order. We then iteratively rearranged the notes into a hierarchy of themes and reached a consensus about physical and virtual curatorial workflow, audience engagement, interaction design, and information acquisition strategies in a virtual exhibition.

3.2 Results from Qualitative Interviews

In this section, we present our findings mainly in two folds. First, to answer **RQ1** (*What are some promises and challenges for audiences to experience exhibitions in social VR, compared with exhibitions in real life?*), we report 3 themes about the promises of virtual exhibitions identified by the expert interviewees, and 3 themes that articulate the challenges of the current virtual exhibitions, along with the strategies recommended by the interviewees to answer **RQ2** (*How to conquer the challenges that the current virtual exhibitions are faced with?*). These proposed strategies will be further validated in *5: Study 2: User Study.*

3.2.1 Promises of Virtual Exhibitions. Our expert interviewees pointed out mainly 3 aspects of what makes virtual exhibitions promising compared with physical exhibitions. First, virtual exhibitions are free of limitations from physical properties such as time, space, money, Covid, and number of participants. Second, virtual exhibitions can provide

audiences with enhanced experiences in appreciating digital native artworks such as VR paintings. Third, audiences can have novel social experiences in virtual exhibitions that are experienced via VR head-mounted devices (HMD) with immersion and embodiment.

Free of Physical Limitations

One of the most significant benefits that virtual exhibitions can offer is that virtual exhibitions can avoid physical limitations (e.g., time, space), and money, which usually downgrade audiences' experiences in physical exhibitions. More specifically, physical exhibitions tend to generate a tremendous cost of money, time, and communication. As most (7/8) of our interviewees mentioned, virtual exhibitions can optimize the visual effect of large installation works without worrying too much about the budget. For example, E1 (Female, 27, Hybrid) mentioned,

> *"In terms of visual effects, virtual exhibitions have greater potential [than physical exhibitions]...For example, once we curated a virtual exhibition featuring a lot of large installations. If we did this exhibition in real life, the budget and the chosen material would have been a great challenge, but we didn't need to worry about these problems since it was a virtual exhibition."*

According to E1, in virtual exhibitions, curators are not necessarily concerned about the budget that might limit the effect of how artworks are arranged in physical exhibitions. Especially when it comes to artworks of large sizes or expensive materials that are needed in the exhibition, virtual exhibitions can be a lot cheaper and more flexible.

In addition to artworks themselves, virtual exhibitions are also budget-saving in terms of other interior decorations, e.g., fountains, waterfalls, fireworks, etc. As E2 (Male, 28, Virtual) noted,

> *"In my virtual museum, I put some waterfalls and streams, which are expensive to maintain them in real life...Also, I put fireworks at the end of the virtual museum, as well as some plants. You don't need to worry about maintaining these things in a virtual museum. All you need to consider is how to make the design look good, because you're in a virtual space where you have unlimited available spaces."*

For E2, an essential part to his virtual museum is the interior landscape design, which could be extremely time and money-consuming to maintain in physical exhibitions. In virtual spaces, there is little limitation in time and budget. Admittedly, virtual exhibitions could generate costs of 3D models, pay for modelers, etc. It is still at a very low cost compared with physical exhibitions, which involve high costs of venues, renovations, logistics, maintenance, etc.

On top of the budget limitation, the spatial properties of the original physical space, e.g., the spatial layout, the floor height, the materials of walls, also constrain curation to a large extent. According to E3 (Female, 32, Hybrid),

> *"Curators basically have an ideal ordering of artworks in the physical space. However, brutally, when remapping works into the physical space, you have to compromise a lot. For example, if I want to have a large projection space for the work in the first space, because the space is not large enough, I can only rearrange the work somewhere else. Therefore, it's actually a mutual negotiation between the curator's planned ordering of the work in the space and the constraints of actual conditions."*

In E3's opinion, curators usually have a plan for which artwork should be placed in which space, crafting the spatial narrative that leads audiences to understand the theme of the exhibition. However, due to actual conditions provided by the existing physical venue, e.g., the spatial layout, curators usually need to compromise their ideal ordering of artworks and the actual physical space that can potentially limit the arrangement, forming *"a mutual negotiation"*.

However, virtual exhibitions have no such concerns about the unchangeable physical properties. E4 (Male, Female, 26, 26, Hybrid) described their experiences in arranging artworks in both a physical and a virtual space,

> *"We have a few works of sculpture that have been physically exhibited in the Chinese National Academy of Arts. The limitation was the floor height, which was only 6-8 meters. However, in our virtual exhibition, the floor height was set to be around 12 meters, making up for the limitation of the physical venue."*

In addition to money, time, and space that could limit the effect of physical exhibitions, another factor that currently hinders the accessibility of physical exhibitions is Covid. In the era of Covid, the accessibility of virtual exhibitions has been valued by our expert interviewees. Five of our expert interviewees described their experiences of canceling offline exhibitions or turning offline exhibitions to online forms due to Covid. For example, one hybrid curator noted,

> *"During the lockdown of Shanghai, we didn't stand a chance to make the exhibition project happen offline, but we were quite urgent, so we made it online instead."* (E1)

According to E1 and the other four interviewees who mentioned Covid as a current obstacle of physical exhibitions, more and more virtual exhibitions have emerged as a back-up plan of offline exhibitions. Covid has become a catalyst of the rapid development of virtual exhibitions.

Apart from Covid, virtual exhibitions also provide accessibility that can break from the physical limitations of geography and traits of audiences. In the context of globalization when international communications have become frequent, virtual exhibitions open up opportunities for cross-border discussions on art. People from around the globe can visit an exhibition at the same time. In particular, exhibitions on social VR platforms, e.g., VRChat, allow users to change their avatars and be whoever they would like to be. Therefore, racism and discrimination toward physical appearances can be ameliorated to a large degree, which is crucial in the context of globalization. E2 described such novel experiences in a VR museum,

> *"In particular, compared with physical exhibitions, what makes virtual exhibitions promising is that you can become anyone in a virtual world. If you're a male, you can use a girl's avatar, or a muscular man. You can also have a tour around the museum or exhibition with anyone from any part of the world."*

Echoing E2's viewpoints about audiences' appearances, another interviewee also mentioned that curators need to pay special attention to audiences' physical traits in physical exhibitions. According to E5 (Female, 39, Physical),

> *"For example, if I make an exhibition [in real life] again, we have to build a space to effectively deliver experiences, but then, since the target audiences were blinded children we couldn't use material that could hurt the children. We need to avoid variables or even accidents that could happen when audiences make interactions or engage with the artwork."*

For E5, considering the physical traits of audiences is really critical when curating a physical exhibition to avoid potential accidents such as harmful materials. However, in virtual worlds, audiences of any physical traits can visit exhibitions without worrying about getting hurt physically.

Enhanced Experiences in Appreciating Digital Native Artworks

Another prominent promise of virtual exhibitions noted by our expert interviewees is audiences' enhanced experiences when appreciating digital native artworks via virtual channels. By digital native artworks we mean artworks created entirely through digital interventions, e.g, AI-generated paintings, VR paintings that use tools such as Google Tilt Brush, 3D models created with software such as Blender. Two of our expert interviewees explained,

> *"For pure digital artists, it is natural for their works to be exhibited via screens. Their works were born in the virtual medium, and thus virtual channels are their works' natural language."* (E3)

> *"...The [virtual] medium that really maximizes the potential of the [digital native] artworks, I think it's good, and it can also democratize that aesthetic experience. Virtual exhibitions definitely have potential."* (E5)

According to E3 and E5, the best way to showcase an artwork is to use the medium that the work was originally created in. Therefore, to maximize the presentation of digital native artworks, it is the most ideal to present them in virtual mediums.

Engaging Social Experiences via Novel Interaction Techniques

Over the past decade of the booming internet and social media, museums and exhibitions have been gradually turned into a social occasion. According to E6 (Female, 30, Hybrid), *"There is [an emerging] concept of turning museums into a social place."* Echoing with her view, E7 (Male, 40, Hybrid) suggests,

> *"It's been a reality that over the last five to ten years, more and more 'wanghong zhan' (influencer exhibitions that draw audiences to take photos and post them to social media) have emerged. The development of the internet has brought such socialization into art exhibitions."*

For E7, due to technological advancement, the booming internet and social media have drawn people to go to exhibition venues, take photos of artworks and themselves appreciating artworks, and post the photos onto social media. Such a social trend has become more and more common in museums and exhibitions. Hence, there is also a trend that curators value and design for social interactions in exhibitions, especially in commercial exhibitions.

That said, another promise of virtual exhibitions is that they can offer some brand new social experiences via novel interaction techniques, e.g., immersive and embodied interactions enabled by VR head-mounted displays (HMDs). One of our interviewees, E2 who just published a virtual museum project in VRChat, received a large amount of positive comments on his work on Chinese social media. We asked why he had chosen to build a museum in VRChat, he responded:

> *"If you use VR headsets, your body language will be projected into the virtual environment. When visiting an exhibition, you can point to some artworks, and your friends will be able to see your movements...Besides body movements, the stereo effect can resemble real-life social experiences, providing users with immersion...These dynamic social mechanics embedded in VRChat were the reasons why I chose this application."*

For E2, there are mainly two novel interaction techniques that made him choose VRChat for his virtual museum project. First, embodied interactions that enable users to project their body language into the virtual environment. When touring around the museum, friends can point to artworks for each other, and they can also experience artwork together. For instance, he mentioned that there was a 3D car model in the museum, *"There's one artwork in which 3 people [models] shake heads in the car model. If you have VR devices, you can shake your heads together with your friends in the car, taking pictures and mimicking the artwork together."* Second, interactions that mimic real-life social experiences can provide audiences with immersion. For instance, the stereo effect in VRChat makes users hear only people near them, which resembles conversations in real life, immersing them in the exhibition like a tour in real life.

3.2.2 Challenges of Virtual Exhibitions and Proposed Strategies. While virtual exhibitions have a lot of potential in terms of its flexibility, virtual medium that better suits digital native artworks, and novel social experiences, our interviewees also cast light on mainly 3 challenges that virtual exhibitions are currently faced with: (1) a lack of adaptation strategies to curate virtual exhibitions when learning from physical exhibitions; (2) technique issues such as curators' lack of skills in programing, game engine, 3D modeling, and a high demand for audiences' network environments and devices; (3) a lack of highlight in the necessity and unique benefits of virtual exhibitions, compared with physical exhibition. To conquer these problems, our interviewees have identified some specific strategies (e.g., design realistic aesthetics and user intuitive interaction techniques to avoid some technical issues for audiences), which will be validated in *5: Study 2: User Study*.

Lack of Adaptation Strategies When Learning from Physical Exhibitions

One prominent challenge for curators who want to make their first attempt in virtual exhibitions is that they lack adaptation strategies when learning from their experience in physical exhibitions, due to the fact that virtual exhibitions are still in their infancy.

The first kind of adaptation that needs to be made is the design of spatial layouts and moving lines. For instance, E3 mentioned, *"When designing the spatial layout of virtual exhibitions, it is a big challenge to make the layout allow audiences to have plenty of freedom to explore, while not making them confused."* Similarly, according to E2, who has expertise in virtual curation,

> *"In 3D virtual environments, people tend to become disoriented more easily, especially if there are return routes, or the captions on the wall are too small and people have to be super close to the wall...This is an example of not making any adaptations according to the characteristics of virtual environments."*

E2 contended that when curating virtual exhibitions, there are a lot of details that need to be adjusted when learning from physical exhibitions. For example, there should be no branching or return routes that make audiences easily lose senses of direction. Also, to minimize the side effects (e.g., disorientation and motion sickness) of VR, the captions on the wall should be larger than those in real life, allowing audiences to see the content clearly at a distance.

Another adaptation that curators need to focus on is their workflow of communicating with the team. When asking the interviewees about their workflow of curating exhibitions, physical curators generally mentioned the step of communicating with construction team, graphic designers, public relation departments, etc. For curators with years of experience in physical curation, they are familiar with the workflow and people they need to reach out to. However, when switching to virtual curation, a large part of communication workflow is changed. Instead of communicating with the construction team, virtual curators need to know how to communicate with programmers and coordinate the whole digital process. For instance, E6, who works mostly on physical exhibitions, mentioned, *"It's (virtual curation) kind of like exploring different possibilities with a web programmer...It's like a very heavy learning curve."* Similarly, E7 suggested, *"I think what makes virtual exhibitions different from physical exhibitions is the required skill sets...Virtual exhibitions actually require a lot of technology literacy, and [the needed skill set] is totally different from physical curation. Sometimes, curators might have a lot of plans, but because of their lack of technology literacy, they can't make those plans come true."* According to the interviewees, even for experienced physical curators, switching to the workflow of virtual curation requires different skill sets from most of their past experiences, which makes virtual curation a hard thing to pick up.

To help curators adapt to virtual curation, 2 virtual and hybrid curators mentioned 2 approaches. First, an increasing number of online exhibition platforms has emerged, such as Spatial [6], Museum of Other Realities [3], and Slime [5]. Curators can use these platforms to curate virtual exhibitions without any experience in game engine or 3D modeling.

As E1 mentioned, *"We hope to directly curate on the platforms [without modeling or coding], but we are still waiting for an appropriate platform builder…I also noticed Slime Engine. I feel like they are still experimenting."* That said, for E1, even though these platforms are promising, a well-established one that can suffice curators' needs and audiences' experiences at the same time has not yet emerged. As E2 noted a drawback of these online exhibition platforms, *"The lower the threshold of this kind of [online exhibition] platforms for curators, the lower their creative freedom may be."* To address this issue, E2 then suggests the second approach– to learn some basics of game engine and 3D modeling, and curate on VRChat. He contended that curating on VRChat does not demand a lot of technical capabilities, and learning some basics of Unity would suffice it to curate a great virtual exhibition.

Technical Issues for Both Curators and Audiences

As mentioned above, curators need to have at least some understanding of technology, e.g., web programming skills, to better facilitate the workflow of virtual curation. Our expert interviewees mentioned some specific technical issues that they had run into during virtual curation, e.g., maintenance of the web page, short of storage, failure to access, etc. As E6 explained, *"I think actually the maintenance part [is hard]. Because we want to make sure it keeps running, and especially there are a lot of projects that also document things or collect data, and then the project will keep expanding, and that would cause problems like the server doesn't have enough storage, and then the whole section shuts down, etc."* For E6, technical problems arise quite frequently during virtual curation, and it is hard to maintain a virtual exhibition because of expanding data such as a growing document about the artworks and artists. For smaller curator teams, technical issues are even more prominent. As E1 mentioned, *"If you focus on virtual exhibitions, you need to have a lot of IT support. For curator teams as small as us, it's still the technical support [that most matters]."* That said, it is critical for virtual curation teams to enhance interdisciplinary collaboration between professional curators and technical experts.

Not only curators would run into technical issues, but also audiences. One major concern that several interviewees (4/8) raised is audiences' availability of the network and devices. For instance, E6 noted,

> *" I have a lot of reservations about virtual [exhibition] projects...For me going to a physical exhibition is like an easy scenario– we don't worry too much about people not coming to our exhibition. But for virtual [exhibition] projects I think people have to make an effort to know the type of the website."*

For E6, physical exhibitions are easily accessible– people just need to walk into the venue. However, the public are mostly not familiar with virtual exhibitions, and therefore curators are worried about audiences not being able to see the exhibition by themselves. Similarly, E6 mentioned, *"Virtual exhibitions seem to be accessible and open, because everyone can make a website, create content with Instagram stories, or Wechat Moments...However, how do you direct them to the virtual exhibition, and whether they have the right device and enough network capacity to access (are all important questions). Especially if there are special devices [like VR headsets] required, a lot of people won't be able to see the virtual exhibition."* According to E7, there are mainly 3 constraints of accessibility to virtual exhibitions– (1) some audiences don't know how to enter the virtual exhibition, e.g., confused about which link to click; (2) audiences' lack of network capacity; (3) audiences' lack of required devices, e.g., VR headsets. These constraints are mainly given rise to by audiences' lack of understanding of virtual exhibitions, which are still very new to the public.

To address this issue of the public's lack of understanding of virtual exhibitions, it is crucial to familiarize the public with virtual exhibitions by making the design features of virtual exhibitions intuitive enough. For example, the aesthetic style should be realistic enough and the interaction techniques should be close to interactions in physical exhibitions. As E2 explained,

> *"Although I could freely customize the aesthetic style in a virtual environment, I didn't want it [the virtual museum] to be too surrealistic, which means I hoped it would look like a real museum. Because almost everyone knows what a real museum is like, and if I make it realistic, audiences will be able to quickly understand the experience. If the style is surrealistic, this would increase the threshold of audiences' understanding."*

For E2, the concept of virtual exhibitions is still new to the public, and therefore if the aesthetics and interaction techniques are distinct from physical museums and exhibitions, it will take some effort for audiences to understand how to navigate in the space and interact with artworks, etc. Therefore, in order to conquer the unfamiliarity with virtual exhibitions at the current stage, it is necessary for virtual curators to make the exhibition like a physical one, including its aesthetic style and interaction techniques.

Lack of Highlights in the Unique Benefits of Virtual Exhibitions

Another concern that most (6/8) of our participants mentioned is the lack of highlights in the unique benefits of virtual exhibitions. To them, some virtual exhibitions, e.g., exhibitions that only feature 2D image artworks, are not convincing enough. For example, as E6 mentioned, *"It's (virtual exhibitions) definitely a trend, and NFT is a trend, but it doesn't mean everyone has to ride on it. I wasn't really initiating all these virtual [exhibition] projects because I didn't see the match or why this [exhibition] project works best online."* For E6, there is a trend of exhibitions and artworks going virtual, e.g., NFT art, however, she's very cautious about such a trend and still waiting for virtual exhibitions that are convincing enough.

Echoing E6's point, E4 noted, *"Currently, there is no difference between virtual exhibitions and games to the public who haven't deeply investigated digitalization. It's just that commercial games have more interactions and dynamic social mechanics, so that's why I think many virtual exhibitions are not convincing enough to the public."* For E4, the reason why virtual exhibitions aren't convincing enough is because they are not distinct from games per se, but with less interactivity and fewer social mechanics, making the current virtual exhibitions less known and popular with the public.

To highlight the unique benefits and distinction of virtual exhibitions, our interviewees proposed several approaches. First, focus on what the unique characteristics of the virtual medium can offer. As E7 explained, *"Virtual exhibitions should not be a direct documentation and reproduction of physical exhibitions. There are many things you can play around with virtual environments such as its unique spatiality and temporality...Curators need to craft novel sensory experiences according to the uniqueness of the virtual medium."* Second, it's important to demonstrate as many 3D models as possible. Compared with 2D images, 3D models can *craft novel sensory experiences* in VR even better, because 3D models in VR are usually not limited in its size and visual effects by the budget or physical space. Additionally, as we mentioned in *3.2.1 Promises of Virtual Exhibitions*, compared with physical exhibitions, virtual exhibitions are more suitable for digital native artworks (e.g., VR paintings, 360 degree videos) to be exhibited. Exhibiting such artworks that cannot be easily exhibited in real life could also offer unique affordances that physical exhibitions cannot.

4 THE VR ART EXHIBITION

Informed by our expert interviewees, we aim to build a prototype of a virtual exhibition in an autobiographical approach, in order to validate the guidelines proposed by the interviewees. In this section, we describe the design goals, principles, process, design outcomes, and implementation to reflect on the emergent insights on virtual exhibition design.

4.1 Design Goals and Principles

Our overall design goal was to explore effective curatorial practices and design strategies to address **RQ3** (*What design strategies are effective to engage audiences in experiencing and acquiring information about virtual exhibitions?*). Therefore, our first design goal was to bring audiences brand new exhibition experiences by providing immersion and new ways of interacting with artworks and social interactions. The second design goal was to help audiences acquire new information and insights on the concept of virtual exhibitions via social interactions, considering the benefits that social interactions contribute to the edutainment of exhibitions.

Drawing on results from expert interviews, we summarize a set of design principles that we aim to follow in our exhibition design:

1) *Realistic Visual Style and Intuitive Interaction Design.* According to the expert interview, due to the public's unfamiliarity with virtual exhibitions, the best approach to lower the learning curve is to make the design realistic and the interaction techniques similar to those in physical exhibitions. Therefore, both the aesthetic style and the interaction techniques, e.g., deliver messages through captions (Figure 3), should be realistic and intuitive.

2) *Featuring Affordances that Only Virtual Exhibitions Offer.* To highlight the unique features of the virtual medium in the context of exhibitions and make virtual exhibitions distinct from physical ones, our exhibition should feature affordances that only virtual exhibitions can offer, e.g., free of physical limitation, innovatively present digital native artworks, etc.

3) *Adaptation Strategies Learned from Physical Exhibitions.* With our lessons learned from physical curation in expert interviews, we aim to adapt and redesign some curatorial strategies in physical exhibition according to the characteristics of virtual exhibitions, e.g., the tendency of disorientation.

Fig. 3. Audiences read captions like in real life

4.2 Design Process

4.2.1 Curatorial Statement. According to our expert interviewees, a clear and meaningful curatorial statement encompassing a central theme is critical to audiences' information acquisition about exhibitions. Therefore, we started with choosing an appropriate theme for our virtual exhibition. Considering that we need to feature affordances that only virtual exhibitions can offer, we brainstormed themes that could feature a lot of digital native artworks which audiences cannot fully experience in a physical setting. To this end, we came up with the theme VR Art Exhibition.

In the curatorial statement, we referred to VR as a dream technology that can allow us to dream infinitely. We invited audiences to think about how VR impacts our relationships with technology and society through looking at art created entirely in VR or via digital mediums.

4.2.2 Call for Artworks. After finalizing the curatorial statement, we published a recruitment post on a WeChat account, calling for digital native artworks that can be exhibited through VR. As of Aug 2022, we had received artworks from 22 groups of artists, including 3D models, VR paintings, AI-generated paintings, digital paintings, VR photography, VR films, and some physical works such as oil paintings and photography of physical objects in real life. See Table 3 in the Appendix for the detailed list of artists and artworks.

To organize the narrative of the theme and also follow the design principles, we filtered the artworks and eventually chose 17 artworks. Our selection criteria were: 1) created completely in digital mediums, e.g., through VR, AI algorithms, 3D modeling, etc. 2) can fit into the narrative of our theme question: how VR as a dream technology affects us as individuals and our society.

We designed 3 chapters for our exhibition. The first chapter is about the history of the development of VR and also VR art. Our aim is to first present audiences with an overview of VR and different types of VR art, and therefore this chapter features artworks created with different digital mediums, including VR paintings, 3D models, VR photography, and VR films. These mediums are not easily accessible in real life, especially for VR paintings that are both three-dimensional and dynamic. For example, there is a VR painting (see Figure 4 & 5) that was inspired by Chinese traditional painting *Wuzhong Landscape* by Shenzhou from the Ming Dynasty. Audiences can walk into the painting and interact with the dynamic mountains, flowing streams, and vivid trees, experiencing ancient Chinese lifestyle from the first-person perspective. This experience would be extremely hard and expensive to replicate in real life, because the dynamic 3D models are both big in size and also hard to maintain.

The second chapter focuses on how digitalization such as VR affects every individual, and therefore all of the artworks in this chapter deliver a message from personal perspectives, e.g., one artist's works are VR photographs taken in VRChat while she travels to different virtual worlds with her friends, demonstrating that people can have as much fun as in real life through social VR. This piece of work was chosen because we think it might change audiences' understanding of photography and social experiences in VR.

The third chapter is related to the impact of VR and technology on society. In this chapter, we first presented artworks that showcase the relationship between humans and nature with the coordination of technology. For example, an artwork is a series of virtual ornaments that use materials resembling algae. Through this work, the artist wants to invite audiences to speculate a future of symbiosis between humans and algae. Audiences can hold the ornaments and place them onto their avatars' faces, and see how they look by turning on the mirror in front of them. In physical exhibitions, such artworks would be constrained in 2 senses: 1) 3D printing and fabrication are expensive; 2) it would be hard to maintain the virtual ornaments, since staff would have to make sure audiences will not damage the artworks and will replace them correctly. However, in our virtual exhibition, there are no such concerns, breaking free from the physical limitation.

4.2.3 3D Environmental Design and Implementation. We designed our 3D virtual environment in Blender. We first built the model of the entire virtual exhibition venue. After the model was done, we found different textures and materials for floors, walls, ceilings, and exhibition caption boards.

We implemented the exhibition using Unity, VRChat SDK [8] and Blender. We took full advantage of the interactive script supplied by VRChat SDK to meet the interactive demand of participants, e.g., VRC Station (script) and VRC Pickup (script) etc. The exhibition was uploaded as a public room in VRChat.

Fig. 4. Audiences outside of the VR painting

Fig. 5. Audiences enter into the VR painting

4.3 Design Outcomes

4.3.1 Key features. Conforming to our design principles, our final design features: (1) a VR painting scroll that audiences can enter (Figure 4 & 5); (2) a 360 degree immersive VR film theater (Figure 6); (3) interactive 3d models (Figure 7); (4) creative spaces that allow users to create freely, leave comments, and socialize (Figure 8).

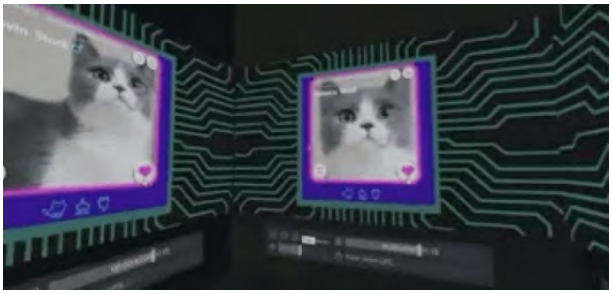

Fig. 6. 360 degree film theater

Fig. 7. Audiences try out the 3D masks

Fig. 8. Creative Space

4.3.2 User Flow. Following the route map (Figure 9), audiences will go through the 9 steps in their flow of visiting our exhibition: (1) audiences onboard and spawn at the entrance of the exhibition hall; (2) audiences enter the first exhibition hall; (3) audiences read the captions of our curatorial statement on the wall; (4) audiences watch videos and look at images; (5) audiences enter the VR painting scroll and interact with VR paintings; (6) audiences participate in VR art creation themselves; (7) audiences watch VR films in an immersive theater; (8) audiences continue to look at images and videos, and interact with 3D models; (9) audiences finish the tour and leave comments with pens on the wall in the closing space.

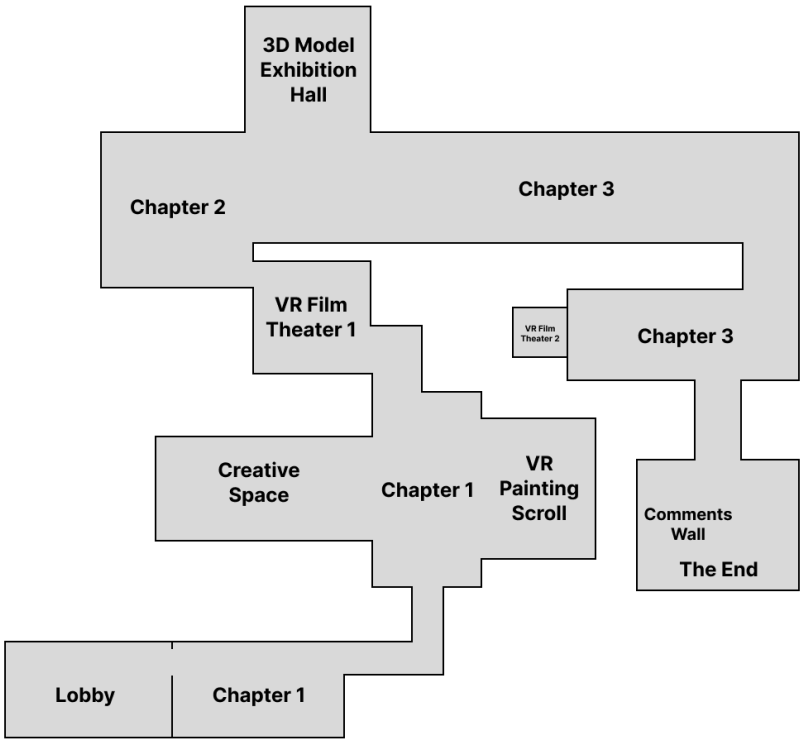

Fig. 9. Route Map of the VR Art Exhibition

5 STUDY 2: USER STUDY

5.1 Methods

5.1.1 Participants. We recruited 30 participants, including the artists, HCI researchers and people who were interested in the VR exhibition to participate in an open event and completed our user study through posting recruitment articles on social media (e.g., WeChat and Instagram). There were 23 males and 7 females with the average age of 23.37 (SD=6.30), who were also respondents of the online investigation from Qualtrics Questionnaire Platform. The detail information of participants can be seen in Table 4 in the appendix.

5.1.2 Procedure. Initially, We set up a WeChat group for our participants to inform them the of information about the exhibition and guides to VRChat. After the exhibition was uploaded to VRChat, all participants entered the exhibition. Participants needed to visit the exhibits and experience the interactive features in the exhibition. The tour time was about two hours and there were two researchers to guide participants in open event (Figure 10 & 11). At the end of the exhibition, all participants filled out a questionnaire which included the SUS questionnaire [14] and 8 other open-ended questions (see Appendix).

Fig. 10. The open event

Fig. 11. Researchers are giving audiences a tour guide

5.1.3 Instrument. We used SUS and open-ended questions as evaluation. (1)SUS questionnaire: The System Usability Scale (SUS) developed by John Brooke is a valuable evaluation tool of products and systems [14]. The SUS consists of 10 questions where each question has 5 choices including strongly disagree (1), somewhat disagree (2), Neither agree or disagree (3), somewhat agree (4) and strongly agree (5). The state Based on [14], The SUS questionnaire can be seen in Table 2 in the appendix.

5.1.4 Data Analysis. First, the data of all participants was merged together in a table in order (P1-30). Then the average score and standard error of each question item were calculated. According to the SUS computational formula [14], the individual score for each participant was calculated, following the average SUS score for all participants. Then for question items of SUS questionnaire, they were divided into two parts: positive items (Q1,Q3, Q5,Q7,Q9 and negative items(Q2,Q4,Q6,Q8,Q10) to analyze according to the SUS [15] and the choice percentage of each question was also considered.

5.1.5 Results from User Study. The final result of the average SUS score is 67.2. The average score for each question in SUS questionnaire can be seen in Figure 12 and the choice percentage of each question can be seen in Figure 13

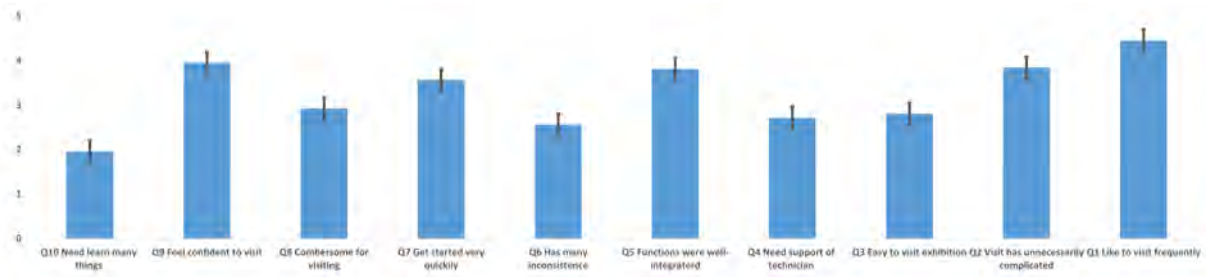

Fig. 12. Mean Value and Standard Error for Each Question of SUS Questionnaire

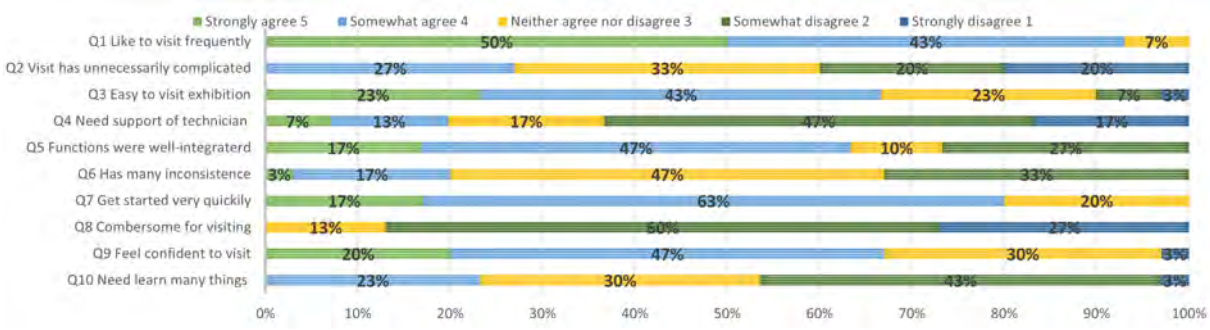

Fig. 13. Percentage of Choice for Each Question in SUS Questionnaire

5.1.6 Quantitative Findings from Survey. After obtaining the average score 67.2 of 30 participants, the next step is to interpret the SUS score using two Acceptance Score Grade approaches (Acceptability Ranges and Adjective Rating) [15]. Based on the two approaches [10], the score is categorized in the Marginal High range and OK rating

Besides, Curved Grading Scale (CGS) assessment version [25] can also interpret the score of SUS. Based on the grade scale, the SUS score of 67.2 is included in the grade scale C category.

Based on the collected data, the average score and percentage of each item are shown in the Figure 12 and Figure 13. Based on the data, the average score of positive items 3.90 is higher than the average score of negative items 2.53. The result indicates that the participants are still giving a more positive assessment of the exhibition system.

5.1.7 Qualitative Findings from Survey. In addition to quantitative findings from survey, we also collected participants' answers to 8 open-ended questions. These questions vary from general questions (e.g., after visiting this exhibition, please share with us your new perspectives about VR / vritual exhibitions; Is there anything else you want to say? Any suggestions/comments are welcomed.) to more specific questions asking participants to compare their experiences in our exhibition and other types of exhibitions (e.g., physical exhibitions). We also asked participants to indicate the features that they liked in the exhibition and also features that they wished to have in future versions.

General Positive Comments on the Novelty and Immersion

In response to the general questions (after visiting this exhibition, please share with us your new perspectives about VR / vritual exhibitions; Is there anything else you want to say? Any suggestions/comments are welcomed.), most participants (21/30) left very positive comments. For instance, 12 participants mentioned it was such a very novel experience that they never had before, and they considered this exhibition *"creative"*, *"innovative"*, and *"visually impactful"*. In particular, one participant commented, *"Compared with traditional interactions, VR enhanced my exhibition experience. While maintaining some realism and immersion like in offline exhibitions, there were unique experiences brought by VR. I believe it's going to be a trend in the future."*

Comparison with Physical Exhibitions

With respect to the question *"Compared with traditional offline exhibitions, what do you like about our exhibition?"*, participants' answers could be categorized into: (1) no cost of tickets; (2) convenience and no need to travel; (3) less social anxiety in an avatar-mediated communication environment where physical appearances are neglected; (4) free of physical limitation for the presentation of artworks; (5) more interactions with the artworks especially VR paintings instead of just looking at pictures in real life; (6) the possibility of touring with oversea friends at anytime.

Participants' Favorite Features

For the features that participants like most, the most mentioned one (11/28) is being able to enter into the VR paintings and interact with the objects in the paintings (key feature 1: a VR painting scroll). What follows next (7/28) is our fourth key feature: creative spaces where participants are transformed to be creators and able to leave comments. Several participants also mentioned they liked such social experiences where people could tour around with friends (especially from oversea), and appreciated our tour guide with many people together.

Suggestions on Future Development

Meanwhile, participants also gave some suggestions on future improvements. In response to questions such as *"Compared with traditional offline exhibitions, what do you dislike about our exhibition?"*, participants mainly complained about 3 aspects: (1) it was difficult to find the right space and participate for those who had never used VRChat before, especially with VR; (2) there were network issues that led to laggings and failure in playing video artworks; (3) there were some bugs in modeling and and lighting, e.g., participants could walk through the walls and the lighting was flickering to some VR users.

6 DISCUSSION

To answer our research questions, our study mainly consists of 3 parts: (1) expert interviews that investigate the promises, challenges, and industry experiences in virtual curation (**RQ1 & RQ2**); (2) the design and implementation of a virtual exhibition in VRChat; (3) a user study that investigates participants' experiences and feedback after visiting our exhibition (**RQ3**).

In this section, we first connect the results from our user study with the preliminary interview results, drawing the conclusion of where the experts and audiences are aligned and where they are divergent on the design features of virtual exhibitions. Then, we point out the connections between our findings and prior work that focus on the application of VR in tangible and intangible cultural heritage [11, 12, 19, 23, 38]. Finally, we summarize the limitations of our work and propose a potential future research agenda in the HCI community.

6.1 Effective Design Considerations in the Virtual Exhibition

Our participants' responses are mostly consistent with what expert interviews suggested. First, in response to what they consider as promises of virtual exhibitions, participants also mentioned their flexibility in time, space, and budget. They were also generally satisfied with the social experiences we had provided in the open event, emphasizing that such communications and social interactions greatly enhanced their engagement in experiencing the exhibition and acquiring information. Additionally, echoing E2's viewpoints of the unique affordances of embodied interactions provided by VRChat, P15 (Female, 21, PC) commented, *I think owning a body of myself in virtual exhibitions is extremely important, as it can enhance my presence and engagement. VRChat is an amazing platform [for virtual exhibitions] as it incorporates a lot of social functions that people would need in real life, such as taking selfies...Taking pictures in the virtual exhibition like what people would do in physical exhibitions immersion."* It demonstrates the importance of incorporating embodied interactions that resemble real life in virtual exhibitions, which can enhance audiences' immersion and engagement with other audiences. Furthermore, participants' complaints also echoed with the expert interviews, since the thing they were most unsatisfied with was also technical issues, including not being able to find the right space and networking issues, which were mentioned in section *3.2.2 Challenges of Virtual Exhibitions and Proposed Strategies.*

Nevertheless, there are also design features drawn from expert interviews that participants wished could be different. For example, in the expert interview, E2 noted that the aesthetic style and interaction techniques should be realistic and

intuitive. However, as P5 (Male, 20, HMDs) commented, *"I hope that in future exhibitions, the design of the exhibition venue could further break free of physical limitations...Even create a non Euclidean geometry space exhibition hall to achieve a dream effect."* For some participants, this exhibition took place in the *"metaverse"*, and therefore they had the expectation of a more surrealistic style in virtual exhibitions [29]. This indicated that audiences' current understanding of virtual exhibitions vary depending on their different levels of understanding of the current technological development trends. It should be noted that P5 had access to VR HMDs, demonstrating his more advanced uses of technology compared with many other audiences. Therefore, it is important for virtual curators to have an accurate target population in order to better serve for their tastes in aesthetics and capabilities of mastering interaction techniques.

Drawn from our expert interviews and user study, we summarize **a list of design considerations that can help audiences to better experience virtual exhibitions:**

(1) Avoid branching or return routes that might cause spatial disorientation in virtual exhibitions;
(2) Take advantage of the VR medium and choose the artworks of digital native mediums that can have better visual effects in VR, e.g., 3D models, VR paintings, panorama videos, etc;
(3) Define the target audience accurately since different groups of audiences with different understanding and accessibility to virtual exhibitions can have different expectations of the aesthetic style and different capabilities of mastering the interaction techniques;
(4) For curators who wish to have more freedom in virtual curation, it is cruicial to master some basics of game engine such as Unity.
(5) For curators who wish to get started with virtual curation quickly, some established platforms such as Spatial [6] and Museum of Other Realities [3] could be taken into account.
(6) For curatorial teams, it is crucial to enhance collaboration between professional curators and programmers.

6.2 Connections with Prior Work

One of the points that our findings resonate with prior work lies in the unique promises of virtual exhibitions provided by the VR medium and social experiences. The approach of enhancing audiences' experiences and information acquisition in virtual exhibitions through VR was mainly because of immersion and embodiment provided by the VR medium [42], since it was suggested that an immersive visualization environment can enhance learning [12, 33]. Furthermore, prior work also suggest the development of VR opens more opportunities for virtual exhibitions without physical limitations such as infrastructure [12, 26].

However, it should be noted here that one prominent finding in this study that is distinct from prior work is accessibility of virtual exhibitions. Breaking free of physical limitations, however, does not necessarily mean greater accessibility to museum content [26]. Since many of our participants in the user study noted that using specific software (e.g., VRChat) and even advanced hardware (e.g., VR HMDs) took them a long time to access. In our expert interviews, experts also demonstrated similar technical concerns that audiences might not be able to access to virtual exhibitions.

In addition to the technical affordances of VR, both prior work and our study suggest that social interactions can enrich virtual exhibition experiences, because a satisfied visitor can share the experience with others [23]. In response to our survey questions, a large amount of positive comments reveal that participants liked our tour guide with a group of people together in the open event. At the open event, participants could communicate with others about their understanding of artworks, and therefore such socialization enhanced learning and information acquisition. However, there are also exceptions in expert curators' attitudes toward socialization. Echoing a previous study [12], both E1 and

E5 indicated they prefer designing a space where audiences can appreciate artworks at their own pace, as E5 noted, *"For me interactions between the audience and artworks are more important than interactions among audiences."* This also indicates a future research topic in virtual exhibitions, i.e., how to balance audiences' focus on exhibits and their social engagement to achieve an overall balanced user experience?

Furthermore, another controversial point about virtual exhibition is the design of moving lines. While some studies suggest a fully guided experience in virtual exhibitions should be avoided for more exploration freedom [12], other works also reveal a higher interaction cost in exhibitions that are less guided and with more complicated interaction and navigation techniques [16]. Our expert interviewee E2, however, suggested the latter viewpoint based on his rich experience in virtual curation.

6.3 Limitations and Future Work

Our user study revealed several limitations of our work. First, the prototype was largely underdeveloped in terms of the roughness of the models and a lack of well-rendered lighting. Second, we have only experimented with virtual curation on VRChat, which might limit its applicability on other platforms. Noteworthily, the networking issue and relatively high learning curve of VRChat were the major reasons that downgraded our participants' experiences. In addition, while most participants suggested they enjoyed the social experiences, exception also exists for those who wished to focus on artworks by themselves.

In the future, we will first focus on resolving the major technical issues in our implementation: roughness of texture and materials and a lack of well-rendered lighting. Second, some other social VR platforms which are experienced through web browsers (e.g., Gather [2] and Mozilla Hubs [4]) are also worth exploration since they are more accessible to most users. Also, in terms of the divergent opinions about the balance between focus and social experiences, and between free exploration and fully guided tours are also worth investigation in future work.

7 CONCLUSION

Through expert interviews, we summarize the promises and challenges of virtual exhibitions. Based on the identified challenges, the interviewees also proposed several strategies to address the issues that might hinder audiences' experiences and information acquisition in VR. Following the expert interview, we used an autobiographical approach to curate a virtual exhibition in VRChat based on a set of design principles drawn from the interviews. In general, our design conformed to 3 principles: (1) realistic visual style and intuitive interaction design; (2) featuring affordances that only virtual exhibitions offer; (3) adaptation strategies learned from physical exhibitions. We held an open event to give participants a tour around the exhibition, and collected their feedback after the event session. Their responses were generally positive, especially regarding the design for VR painting scrolls, creative spaces, and the socialization in our exhibition. Participants also gave some suggestions and complaints mainly about how difficult and troublesome it was to use VRChat for the first time, networking issues that led to laggings and failure to play videos, and some bugs in the models and lighting. Through the user study, we draw a set of validated design guidelines for future virtual curator, social VR designers, and HCI researchers.

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8 APPENDIX

8.1 System Usability Scale

No.	Questions	Scale
1	I think I would like to visit this kind of exhibition frequently	1 to 5
2	I found visiting the exhibition was unnecessarily complicated	1 to 5
3	I thought it was easy to visit the exhibition	1 to 5
4	I think that I need the support of a technician to visit the exhibition	1 to 5
5	I thought the various functions in the exhibition were well-integrated.	1 to 5
6	I thought there was too many inconsistencies in this exhibition	1 to 5
7	I think the majority of users will be able to get started with this exhibition very quickly	1 to 5
8	I thought the exhibition very cumbersome for visiting	1 to 5
9	I felt very confident visiting this kind of exhibition	1 to 5
10	I need to learn a lot of things before I could visit this kind of exhibition	1 to 5

Table 2. SYSTEM USABILITY SCALE

ID	Artist Genre	Artwork Genre
A1	Screenwriter	Video Work
A2	Screenplay Analyst	Video Work
A3	Crypto Artist	3D Animation
A4	Painter	Digital Painting
A5	Painter	AI Painting
A6	Installation Artist	3D Model
A7	Photographer	VR Photography
A8	New Media Artist	Video Work
A9	Graphic Designer	3D Model
A10	Pop Artist	Digital Painting
A11	Painter	VR Painting
A12	HCI Researcher	Video Work
A13	New Media Artist	3D Model
A14	New Media Artist	Digital Painting
A15	Programmer	Digital Painting
A16	Digital Painter	VR Photography
A17	Painter	VR Painting
A18	Painter	3D Model
A19	Painter	3D Model

Table 3. The List of Artists and Artworks

8.2 The List of Artists and Artworks

8.3 The List of Participants

8.4 The List of interview questions

8.5 The List of 8 Open-Ended Questions

ID	Gender	Age	Nationality	Device
P1	Male	18	China	PC
P2	Male	19	China	PC
P3	Male	22	China	HMDs
P4	Male	25	China	HMDs
P5	Male	20	China	HMDs
P6	Male	19	China	PC
P7	Male	23	China	HMDs
P8	Male	19	China	PC
P9	Male	19	China	HMDs
P10	Male	20	China	HMDs
P11	Male	24	China	PC
P12	Female	22	China	PC
P13	Female	25	China	PC
P14	Male	28	China	PC
P15	Female	21	China	PC
P16	Male	35	China	PC
P17	Female	19	China	HMDs
P18	Male	18	China	PC
P19	Male	21	China	PC
P20	Female	20	China	PC
P21	Female	22	China	HMDs
P22	Male	46	China	PC
P23	Female	24	China	HMDs
P24	Male	32	China	HMDs
P25	Male	22	China	PC
P26	Male	22	China	HMDs
P27	Male	25	China	HMDs
P28	Male	27	China	HMDs
P29	Male	20	China	HMDs
P30	Male	23	China	HMDs

Table 4. The List of Participants

Theme	Specific Question
1. Demographics	Can you briefly introduce your experiences as a curator? (How long have you been a curator? What museum/gallery did you work for? What exhibitions have you ever curated/produced?)
2. Physical Curatorial Process	Based on your experience, could you describe the overall curatorial process when delivering a physical exhibition? What are the major steps of curating an exhibition from start to finish? How do you choose the theme of an exhibition? What information do you consider essential to be included in an exhibition? What is your order of information delivery? Like your primary information, secondary information, etc. (e.g., introduction to works of art, authors, etc.) What are some factors that you have most concerns about during the whole physical curation process? (e.g. physical environment limitations, curatorial logistics, transportation & restoration, etc.) Does route planning matter to curators? How do you usually plan the visitors' routes? Do forms/mediums of artworks matter to you? How do forms/mediums of artworks influence the way you curate an exhibition?
3. Digital Curation	Have you had any digital curation experiences? If yes, can you describe a most memorable one? If you were given a chance to curate an exhibition in VR, what would be different from your curatorial process in the physical curation? What are the factors that you have most concerns about during the whole digital curation process? (e.g. virtual space design / spatial influence, communication, modeling, etc.) What's the most challenging step in the digital curation workflow compared to physical ones? Why and how do you think it could be enhanced?
Attitudes towards digital curation as a visitor	Have you paid any visits to virtual exhibitions yourself? (if no, can you imagine what you will like/dislike about it according to the video) What do you like/dislike about it? What do you think about some exhibitions held through VR, or in what is now popularly called Metaverse? What do you think is the primary motivation of attending a virtual exhibition?
Visitor Experience	Can you describe your experiences when you try to make the audience engaged with the exhibits? How did you do it? Did it work out well? Do you consider social interactions important to an art exhibition? What aspects do you pay a lot of attention to make sure visitors have good experie

Table 5. The List of interview questions

ID	Specific Questiion
Q1	After visiting this exhibition, please talk about your new idea/understanding of VR/ virtual exhibition.
Q2	In what ways do you think our exhibition has advantages over other virtual exhibitions (WEB exhibitions, exhibitions viewed through a browser, etc.)?
Q3	In what ways do you think our exhibition has disadvantages over other virtual exhibitions(WEB exhibitions, exhibitions viewed through a browser, etc.)?
Q4	Compared with visiting a traditional offline exhibition, what advantages do you think our exhibition format has?
Q5	Compared with visiting a traditional offline exhibition, what disadvantages do you think our exhibition formart has?
Q6	What features/designs do you like about this exhibition? (For example: dynamic VR paintings that can only be viewed in virtual media, free creation space next to VR paintings, social experience based on VRChat in the process of viewing exhibitions, etc.)
Q7	Are there any other features/designs in this exhibition that we don't have yet that you would like us to develop?
Q8	Is there anything else you want to tell us? Any suggestions, comments, etc. are welcomed.

Table 6. The List of 8 Open-Ended Questions