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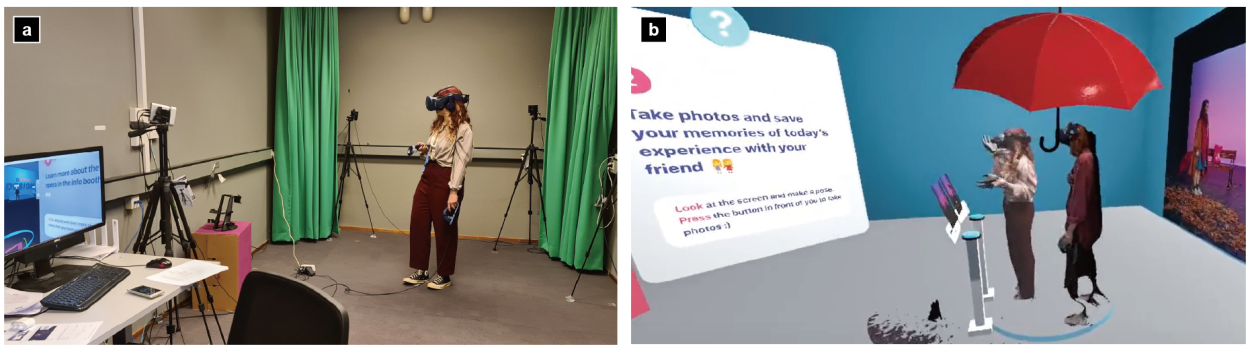

Fig. 1: (a) Physical setup for one participant in VR, (b) Two participants' point clouds in the Photo Zone (spectator's view).

Abstract—The latest social VR technologies have enabled users to attend traditional media and arts performances together while being geographically removed, making such experiences accessible despite budget, distance, and other restrictions. In this work, we aim at improving the way remote performances are shared by designing and evaluating a VR theatre lobby which serves as a space for users to gather, interact, and relive the common experience of watching a virtual opera. We conducted an initial test with experts (N=10, i.e., designers and opera enthusiasts) in pairs using our VR lobby prototype, developed based on the theoretical lobby design concept. A unique aspect of our experience is its highly realistic representation of users in the virtual space. The test results guided refinements to the VR lobby structure and implementation, aiming to improve the user experience and align it more closely with the social VR lobby's intended purpose. With the enhanced prototype, we ran a between-subject controlled study (N=40) to compare the user experience in the social VR lobby between individuals and paired participants. To do so, we designed and validated a questionnaire to measure the user experience in the VR lobby. Results of our mixed-methods analysis, including interviews, questionnaire results, and user behavior, reveal the strength of our social VR lobby in connecting with other users, consuming the opera in a deeper manner, and exploring new possibilities beyond what is common in real life.
All supplemental materials are available at https://github.com/cwi-dis/IEEEVR2024-VRLobby.

Index Terms—Perfoming arts, Virtual reality, Collaborative interaction, Empirical studies in HCI, User studies

1 Introduction

The importance of arts in our society is unquestionable. Apart from cultural affiliation [5], these creative expressions help individuals to develop both emotional and cognitive processes [35]. The reasons why audiences go to the performing arts range from feeling part of a community of interest (*spiritual*), getting an emotional hit (*emotional*), being intellectually challenged (*intellectual*), and enhanced socialisation (*social*) [63]. For example, the most recurrent themes when opera-goers were interviewed about the cultural value of opera were: history of attendance (32%), emotion (21%), other people (17%), and production (17%) [44]. "We found that other people performed an essential function in how respondents contextualized and made sense of their own opera-going history" [44].

Thanks to technological advancements, attending art performances remotely is a valued alternative to in-person experiences [49]. In some cases, it is the only alternative due to distance, timing, budget, and other restrictions. Even if there is a complete body of work on the computational support of remoteness for performing arts, like dancing [57, 68], the study of the audience experience is still an open challenge. In the past, research has focused on a number of relevant areas, such as live streaming of theatrical performances to cinemas [42], the possibilities of audience participation [59], and the relationship between audiences and performers [64]. In this context, we move a step forward by investigating the shared experience between audience members in social Virtual Reality (VR). We focus on the experience in a virtual lobby after watching an opera. Specifically, the "lobby" is a communal area where the audience comes together before and after a show in a cinema or in a theatre, and it plays a vital role in enhancing the overall experience [25]. In this work, we aim to improve the current way remote experiences are shared by designing and evaluating a "virtual theatre lobby" as a place to connect remote opera audiences and foster social values. We consider social VR as a valid alternative for collaboration and communication [32], extending previous work exploring movies as the context of interaction [39, 53].

In our previous work [28], we proposed an initial conceptualisation of VR theatre lobby based on the high-level motivations for theatre-goers [63]: *spiritual*, *emotional*, *intellectual*, and *social* engagement. While the work [28] provided the theoretical lobby concept and possible design direction, in this work, we present the design and evaluation of a complete VR lobby prototype built with Unity for a socially enriching

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remote opera-watching experience. A unique value of our system is that allows for a highly realistic representation of the users in the virtual world (see Figure 1). After an initial implementation of the design, a first test with experts (N=10, i.e. designers and opera enthusiasts) experiencing the system helped us to refine the VR lobby and improve the overall usability. The second iteration of the implementation was tested in a controlled, between-subjects study (N=40), to better understand the benefits and drawbacks of the lobby as well as to compare the experience of individuals and paired audiences. We follow a mixed-method approach to analyse the user experience both quantitatively and qualitatively, through the use of a post-experience questionnaire, semi-structured interviews including questions about the experience (general, interaction, and social), and recordings of user navigation in the VR space. Despite several studies being conducted investigating the impact of performing arts experiences in VR [18,46], there is still a lack of standardized questionnaire methodology to evaluate the user response in this type of social VR experience. Therefore, we fill this gap by designing and evaluating a questionnaire aiming at understanding post-performance lobby experience in VR. Specifically, we consider aspects related to *Cognitive*, *Affective* and *Spiritual* engagement to the opera and the VR lobby, together with *Presence* and *Immersion* within the VR environment. Our contributions can be summarised as follows:

- We design, implement, and evaluate a VR theatre lobby as a dynamic space for remote users to communicate and interact following their virtual opera experiences;
- We propose and validate a questionnaire for assessing VR theatre lobby experiences;
- We present a quantitative and qualitative analysis of experiencing the VR theatre lobby, comparing the experience of single users with respect to pairs.

Our results highlight three benefits of the VR lobby: connecting and sharing with others, having an immersive opera experience, and being free from realistic constraints.

2 Related Work

2.1 The Value of Theatre and Lobby Experiences

Previous works have identified several motivational typologies for attending opera and theatre, including escapism and entertainment, edutainment, personal enrichment, and social hedonism [63]. These have been mapped into four high-level goals [28,34,36]: *emotional, social, intellectual*, and *spiritual*. One important aspect of the theatre and opera experience, that contributes to the aforementioned goals, is the lobby: the common space where audiences gather before and after the event. Literature suggests that activities in the lobby enrich the overall experience. For example, Cova and Caru [7] describe the performance space as existing in a dimension apart from daily life, with the theatre lobby acting as a buffer "between the real world and the magical world of the theatre" [3,25]. Kilpatrick [25] further suggests that dynamics of the lobby alter audience responses to performance since in this immersive space audiences can process the physical or sensual experience after the show [63], in an environment of shared intimacy [7]. These activities allow audiences to connect with friends and strangers [12,63], making the lobby the center for *social* intercourse that allows them to be seen by others, watch people, or have the opportunity to collect autographs and engage in post-show discussions [25]. Such interactions support community building [12,25] by creating a sense of cultural identity [63]. Apart from the social and emotional goals, the lobby experience can support *intellectual* goals by further connecting audiences to the performance, and to each other [47]. For example, lobby activities can provide audiences with additional information about performance. Finally, the lobby can help *spiritual* goals by having audiences write down what they thought of images that are evocative of a performance [12].

Our previous work highlighted four main goals for theater-goers: *emotional, social, intellectual*, and *spiritual* [28]. In this work, we use these concepts as a springboard to design, prototype, and evaluate a VR Lobby experience that supports these high-level goals.

2.2 Immersive Social VR Experience in Arts and Culture

Social Virtual Reality (Social VR) refers to virtual environments where multiple users can join and communicate with each other. Commercial social VR platforms such as *Roblox*[1], *VRChat*[2], *RecRoom*[3] and *Bigscreen*[4] enable immersive and remote social interactions with unique social mechanics. *Roblox*, for instance, supports in-game creation and distribution but has also hosted live concerts and events. Likewise, *Bigscreen* specializes in social movie experiences and playing games with others. The increasing popularity of these platforms has shown the capacity of social VR as a new medium for remote communication [32].

The advent of commercially available social VR platforms has led researchers to explore how the medium can be used to share meaningful experiences, and in kind, how such experiences can be assessed. The potential of social VR to conduct collaborative work has been amply studied in the literature [2,4,9], as well as its ability to create common environments for learning and sharing knowledge [41,45]. Researchers have explored the potential of social VR in areas such as health care [30], food [37], learning and training [1,15,27,69], artistic design [52], and museum exploration [50]. These social VR applications are well-defined and offer a specific scope for social interaction.

In this work, we aim at exploring how social VR can be used to have meaningful conversations and shared discussions after witnessing a shared media together, in a social VR lobby. Moreover, in our evaluation, we aim to see how the VR lobby experience changes based on whether it is experienced alone or together, thus trying to define the *added value* of socially experiencing VR.

2.3 Evaluating Social VR Lobby Experiences

User experience can be measured explicitly, through the use of questionnaires, or implicitly, by evaluating the user behaviour when navigating the VR space. The spatial dynamics of social interaction, such as exploratory movements and proxemics, play a significant role in understanding interpersonal relationships and behavioural patterns within social VR experience. For instance, an exploratory behavioural analysis of users experiencing a social VR movie has been presented in [51]. Digital proxemics has also emerged as a novel and unique area of research focused on the effects of social proximity on interactions within VR spaces, to detect which social cues are the most influencing and therefore are needed to ensure presence and immersion [26,66].

When explicitly evaluating user experience in VR, an important parameter is how effectively they can enclose the user, making them feel embodied and present in the surrounding environment. For this aim, several factors are considered. Immersion is defined as "a form of spatiotemporal belonging in the world that is characterized by deep involvement in the present moment" [17]. Previous studies on VR have emphasized the immersive characteristics of user experience, using questionnaires such as the Immersive Tendency Questionnaire (ITQ) [60]. Further, immersion significantly impacts user satisfaction and loyalty [20]. The sense of presence has also been discussed by scholars [58]; among these, the Igroup Presence Questionnaire (IPQ) scale [55] has been used in virtual reality and mixed reality studies [54,56]. In addition, engagement is a central concept in user experience. Measuring psychological engagement is important beyond behavioral participation [48], as it is linked with motivation and influences satisfaction [22,43].

Even though several studies have been conducted investigating the impact of performing arts experiences in VR, there is a lack of standardized questionnaires that can aid in evaluating such experiences across multiple factors. In [18], authors evaluate the user experience of theater performance in a cinematic setup and through a VR headset; whereas concepts of presence and immersion are evaluated through questionnaires, they measure engagement implicitly, through the use of EEG signals. Scorolli et al. [57] evaluate the aesthetic and social experience of a tango concert in different levels of immersiveness. Other

[1]Roblox: https://www.roblox.com/
[2]VRChat: https://hello.vrchat.com/
[3]RecRoom: https://recroom.com/
[4]Bigscreen: https://www.bigscreenvr.com/

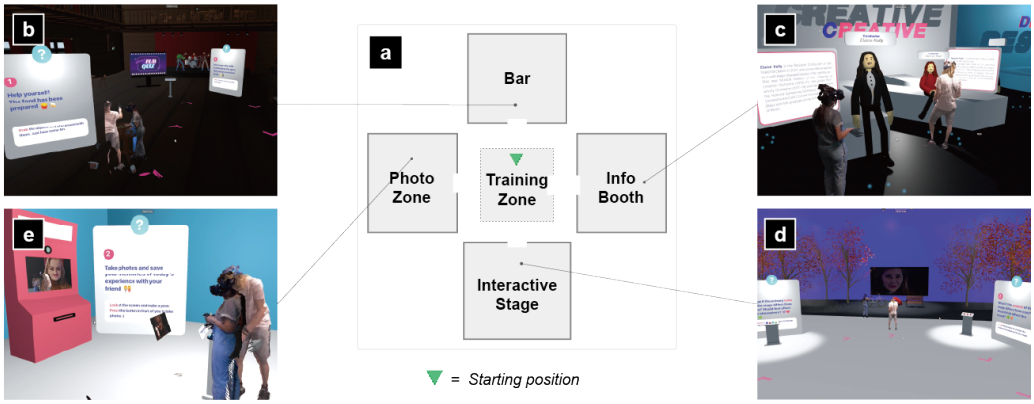

Fig. 2: Diagram showing the design of initial VR lobby, including (a) a floor plan of the VR lobby, and the four main rooms it is comprised of: (b) a Bar (c) an Info Booth (d) an Interactive Stage, and (e) a Photo Zone.

engagement measures in VR experiences for theater and performing arts focused more on usability aspects such as cognitive load and ease of use [46], as they were designed with an educational purpose.

In our study, we aim to compare the effect of experiencing the VR lobby in a social setting, as opposed to experiencing it alone. To do so, we construct a questionnaire that can encompass different aspects of user experience in VR environments, such as engagement, immersion, and presence. We adopt items from existing questionnaires as their validity has already been proven in studies involving VR, learning, and entertainment [20,22,29,48,55,67]. We opted not to explicitly evaluate any social aspect in our questionnaire, as it would not apply to all the settings and could bias our results.

3 Part 1: Designing a Social VR Lobby Experience

Part 1 introduces our social VR Lobby prototype and the results of a preliminary study with experts (N=10). The VR lobby was constructed based on a conceptualized design presented in [28], where each of the four rooms corresponds to four high-level motivations for attending the theatre: *social*, *intellectual*, *spiritual*, and *emotional* engagement [63].

3.1 Initial VR Lobby Design

To offer a comprehensive VR Lobby experience, we developed two distinct scenes in Unity: a Cinema room and a Social VR Lobby, featuring four activity rooms and a Training zone. The audience begins their experience by watching an opera in the Cinema room (first scene) and then transitions to the Social VR Lobby (second scene). Once inside the Social VR Lobby (Figure 2(a)), the audience starts at the Training zone, where they become familiar with VR controllers before engaging in the 6DoF experience. The main focus of this paper is to create and evaluate the Social VR Lobby - the four rooms for audience engagement (Section 3.1.1). For this reason, we have designed the Cinema room and the Training zone only with essential elements for opera-watching and controller training purposes (Section 3.1.2).

3.1.1 Four rooms for audience engagement

Bar (Figure 2(b)) was designed for *social engagement*: people can grab beers and fries while discussing the opera. There was also a quiz section with a list of questions (e.g., "Can you relate to the protagonists in the opera?") provided by the opera creators to provoke and guide audience reflection and discussion.

Info Booth (Figure 2(c)) provided background information about the opera through text, images, and 3D avatars for *intellectual engagement*. People could read plot summaries and view photos of various scenes. The core opera team members, including protagonists, were animated as 3D avatars, and interactive pop-up screens displayed brief introductions for each person.

Interactive Stage (Figure 2(d)) facilitated interaction with props and the stage, fostering *spiritual engagement*. People could alter the stage color (from purple to pink, green, cyan) and the seasonal background (i.e., autumn to spring, winter) of the set.

Photo Zone (Figure 2(e)) offered an opportunity to capture and save the experience by taking photos for *emotional engagement*. People could grab and play with props from the opera (e.g., umbrellas, hats, etc.) and utilize a photo machine in the VR space to take and print photos.

3.1.2 Additional design elements for overall experience

Cinema room was a darkroom with a 2D screen, adapted from the VR Cinema for Mobile asset[5] from Unity Asset Store.

Training zone in Figure 2(a) was created to train fundamental controller functions, including teleportation, grabbing, and button clicking. It was surrounded by translucent blue walls and positioned in the center of the VR lobby. Instruction panels with images and descriptions of the VR controller functions were available.

Other design elements There were arrow guides on the floor as a subtle path indication, however, the four rooms were not given a particular number or order.

3.2 Understanding and Improving the VR Lobby

3.2.1 Participants and setup

The study was conducted at the CWI building from July 18th to August 2nd, 2022. A total of five pairs (N=10), who already knew each other, participated in the study. Participants were recruited via flyers and social media channels. We collected participants' statistics including age (m=25.8, sd=2.8), gender (M=2, W=8), jobs (student, architect, contents moderator, etc.), interests in music/opera (m=5.7, sd=1.06, scale of 7), and experiences in VR (novice=6, knowledgeable=3, expert=1). They were recruited for their interests in opera and their experience in VR design. Two researchers conducted the study simultaneously in two separate VR rooms. Each session lasted approximately 1 hour and 10 euros voucher was given as compensation.

3.2.2 Technical setup

The VR lobby application was built in Unity3D on top of an open-source end-to-end system to transmit volumetric contents in multi-party real-time communication [23,62]. We selected a volumetric communication system as it was shown that highly realistic representations provide a better sense of presence and immersion as compared to avatars [38,39]. For more details about the system implementation, we refer the readers to [62]. In each session, two participants joined the VR lobby application from different VR rooms, which were equipped with a Vive Pro Eye HMD, controllers, and 3 Azure Kinect cameras attached to a VR-ready machine. They were captured in real-time by depth cameras and represented in the VR world as point clouds. One technical assistant joined the application from another room using a VR-ready laptop, with no representation, to see and video-record the session using OBS studio.

[5]VR Cinema for Mobile asset: https://assetstore.unity.com/packages/3d/props/interior/vr-cinema-for-mobile-150120

3.2.3 Procedure

At the start of the experiment, researchers gave a short introduction and asked participants to sign the consent form. The study consisted of three steps:

Step 1: Participants individually watch digital opera (9 min). Participants were physically seated on the chair at the center of the VR room; in VR, participants individually watched in the Cinema room a 2D digital opera, named <Close>[6]. The 8 minute video is a story about two protagonists meeting face to face for the first time after online dating during lockdown in 2020. Participants were placed at the center of the Cinema room when they entered, and the 2D opera started playing immediately. For this scene, we disabled the user representations and microphones to prevent distractions and undesired variables. While it is a 6-DoF experience, the participants could not teleport as they had a fixed position without controllers.

Step 2: Participants (as pairs) explore the Social VR Lobby with Think-aloud method (15 min). After watching the opera, participants took a 2-5 minute break by taking off the VR headset; meanwhile, the researchers removed the chair and set up the next part. The participant wore the VR headset again after the break (Figure 1(a)); in VR, their point cloud representations were enabled (Figure 1(b)). Participants started the experience in the Training zone, where they were taught three interaction methods - teleport, grab, and button clicks. After the training, they were asked to freely explore the four rooms - Bar, Info Booth, Photo Zone, and Interactive Stage – with no particular sequence, using a 'Think-aloud' method [8]. Meantime, the researchers checked and noted whether each participant performed all the intended interactions (e.g., Participant clicked the button to take a selfie in the Photo Zone).

Step 3: Participants individually answer semi-structured interview (10 min). After participants had sufficient VR lobby experience, the researchers conducted a semi-structured interview. The interview was conducted individually in a non-VR setting, and the entire conversation was recorded for analysis purposes.

3.2.4 Data Analysis

All the interview audio and the VR session screen recording audio were transcribed into texts and coded using *Dovetail*[7]. We conducted a thematic analysis [33] of the collected data. Three researchers first individually reviewed and labeled the text, organized the labels into themes, then came together to make an agreement on the user requirements for improving the social VR Lobby experience (results are in Section 3.3). Additionally, the notes taken during Step 2 of the test were separately collected and used as a guideline for improving the usability of the entire VR lobby experience (results are applied in Section 4.1).

3.3 Design Requirements on Social VR Lobby

Based on the data analysis, we gathered design requirements to ameliorate the initial social VR Lobby experience.

3.3.1 Selecting and merging from four to two rooms

While the four rooms were built to serve four distinct audience motivations, measuring the engagement of each room was a challenge. Participants perceived and engaged with each room differently based on their personal interests. For example, one pair actively discussed their past experience while answering the pop quiz at the *Bar* (built for *social engagement*); on the other hand, another pair had low interest in the quiz and spent more time in the *Interactive Stage* (built for *spiritual engagement*), having an active discussion on the preference over the season and color changes. Thus, it was no longer rational to maintain the four-room structure and rate them separately. Additionally, many participants claimed the lobby was too empty and lacked details, which degraded their overall experience. Some complained that the limited interaction with background objects - e.g., unable to go upstairs when they see stairs - broke their *immersion*.

Consequently, we decided to focus and improving the design of two rooms, namely *Interactive Stage* and *Photo Zone* which were the most praised during the interviews.

3.3.2 Navigation: smooth and clear, but with freedom

The navigation, both transitioning from the cinema to the lobby and the exploration between rooms, was another critical issue to the user experience. Some mentioned that the *Cinema room* and the *Lobby* felt like two distinct spaces, as they were teleported directly from the cinema room to the middle of the lobby. Thus, there should be a smoother transition between the cinema room and the lobby.

While Benford [3] suggested that the trajectory through a virtual world affects the user experience, we decided not to control the user path. Participants claimed that they wanted to have control over the space by freely exploring the rooms while still benefiting from the 'arrow guides'; also, they had a personal preference for the routes when visiting the four rooms. Therefore, the lobby should provide sufficient and clear navigation guides and not force them to follow defined routes.

4 Part 2: Evaluating the Social Experience in the VR Lobby

In Part 2, we conducted a controlled study to compare the experiences of individuals and paired participants in the enhanced social VR lobby. Following a mixed-method approach, we assessed it along three aspects: questionnaire responses (quantitative), user behavior analysis, and post-experience interviews (qualitative).

4.1 New VR Lobby Design

The VR lobby was meticulously designed to encourage social interaction for pairs while ensuring a comprehensive experience for individuals. Based on the design requirements in Section 3.3, the primary changes were to remove *Bar* and *Info Zone* and to improve details and interactions in the remaining ones, *Interactive Stage* and *Photo Zone* (Figure 3).

4.1.1 Two rooms for audience engagement

Interactive Stage. In the first study, the possibility of interacting and changing the VR space led participants to discuss their preferences. Thus, a third interaction point was added (Figure 3(b)), where participants could alter the set from the original stage set, composed of a red umbrella, a bicycle, and a bench, to a bus station and cafe.

Moreover, participants had access to the main stage and could interact with the objects that were previously not accessible. The previous interaction of altering the background color remained the same, while one more season (i.e., summer) was added to the second interaction point to complete the four seasons.

Photo Zone. In the first study, paired participants took photos together at least once, leading to further conversation about general VR interaction and the opera experience. Thus, we added one more photo spot and an additional 'photo sending' experience while improving the usability with sound, haptics, and interactions. Thus, the new Photo Zone (Figure 3(c)) consisted of four interaction points: a mirror and grabbable props, a photo machine with the main character avatars, a photo machine with a changeable background, and a mailbox for sending photos.

4.1.2 Additional design elements: for overall experience

The layout was refined for a theater lobby ambiance with a two-floor design. The training zone was located on the 2nd floor; on the ground floor, Interactive Stage and Photo Zone faced each other in the hallway to avoid giving priorities over one another. The remaining ground floor space, beneath the training zone, was transformed into a café with interactable drink objects. Usability issues noted in Section 3.2.3, such as participants not noticing or performing intended interactions, were resolved with interface improvements.

Cinema room and Training zone The Cinema room was the same as in Part 1. The new Training zone was a dark room designed to provide a seamless transition from the cinema room to the lobby, as a result of critics in the previous test (Section 3.3)

[6]<Close> by Hannah Peel: https://www.youtube.com/watch?v=ZyQTSW6QSHU by Irish National Opera

[7]Dovetail: https://dovetailapp.com/

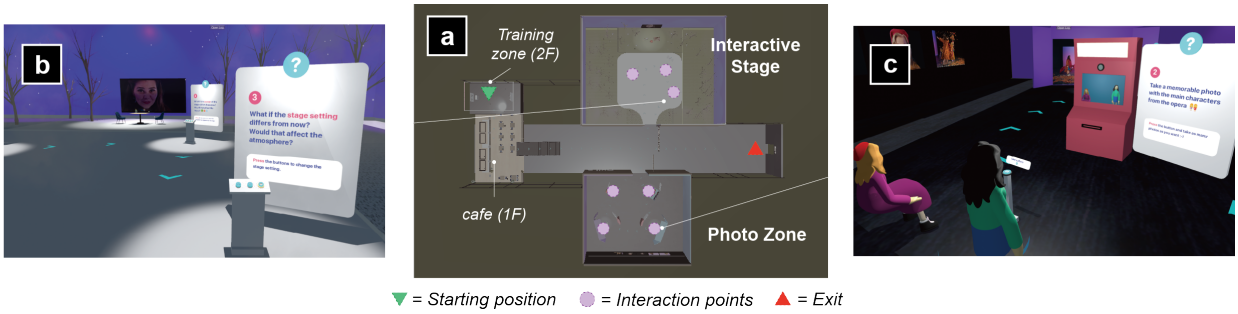

Fig. 3: (a) A floor plan of the new VR lobby, including (b) an Interactive Stage with a third interaction point, and (b) a Photo Zone with a photo machine with the main character avatars.

Table 1: Questions used in the experiment, with relative loadings for each factor. Questions in red were omitted from EFA as their correlation with existing items was above 0.8. Items in bold are selected for the final questionnaire (loading on one factor > 0.4 and difference in cross-loading of at least 0.2).

	Question	Factor 1	Factor 2	Factor 3	Factor 4
1	**I felt free to interact with the environment as if I was in the real world.** [20]	0.3937	0.0131	-0.0450	**0.6930**
2	**I felt detached from the outside world.** [20]	0.0882	**0.4495**	-0.0982	-0.0089
3	**I felt completely immersed that I forgot about my everyday concerns.** [20]	0.0586	**0.5713**	0.0904	-0.0039
4	**I felt free to explore and look where I wanted.** [20]	0.0428	**0.4791**	0.0367	0.2079
5	I felt free to move around in the VR experiment. [20]	0.0657	0.3944	0.0530	0.3007
6	**I feel happy during the VR experience.** [22]	**0.5153**	0.3068	0.0866	0.0565
7	I feel bored during the VR experience. [22]	0.3104	-0.1854	0.0765	-0.1070
8	**I feel excited by the VR experience.** [22]	**0.8154**	0.0833	-0.0955	-0.0002
9	**I liked the VR experience.** [22]	**0.7734**	0.1138	-0.1718	0.2536
10	I feel the VR experience is interesting. [22]				
11	**The VR experience is fun.** [22]	**0.7610**	-0.0443	-0.1196	0.3150
12	What I saw in the VR experience made me curious to learn more about it. [22]	0.4878	-0.0803	-0.0446	0.3478
13	**I would discuss what I learned at the VR experience with other people.** [22]	**0.4513**	0.0436	0.1837	-0.0861
14	I am curious to discover how I can interact with the objects within the VR environment. [22]	0.3707	0.3478	0.0210	0.0700
15	**This opera helps me to escape daily life.** [63] (adapt.)	-0.0758	0.0365	**0.8322**	0.0820
16	**This opera is inspiring and makes me creative.** [63] (adapt.)	-0.0197	0.0841	**0.8767**	-0.0056
17	The visuals in this opera are very appealing. [63] (adapt.)	-0.0886	0.4446	0.5572	-0.0186
18	**This opera helps to give my life meaning and purpose.** [48]	0.0572	-0.1449	**0.8601**	0.1912
19	**This opera helps me to connect to something greater than myself.** [48]	-0.0616	0.0159	**0.8184**	0.0659
20	**I thought the VR experience was enjoyable.** [29]	**0.7850**	0.2798	-0.1019	-0.0067
21	I thought the VR experience was exciting. [29]				
22	**I thought the VR experience was moving/interesting.** [29]	**0.7838**	0.0985	-0.0128	0.1458
23	**I would like to experience the VR opera again in the future.** [67]	**0.7071**	-0.0590	0.3624	-0.2311
24	**I would recommend the VR opera experience to my friends.** [67]	**0.8718**	-0.0398	0.1110	-0.1915
25	**How aware were you of the real world surrounding while navigating in the virtual world (e.g., sounds, room temperature, other people?)** [55]	-0.2479	**0.4947**	-0.0447	0.2123
26	How real did the virtual world seem to you? [55]				
27	**I had a sense of acting in the virtual space, rather than operating something from outside.** [55]	0.0641	**0.8301**	0.0471	-0.2363
28	**How much did your experience in the virtual environment seem consistent with your real world experience?** [55]	-0.0291	-0.0293	0.0889	**0.8685**
29	**How real did the virtual world seem to you?** [55]	0.0118	-0.2583	0.1859	**0.8092**
30	**I did not feel present in the virtual space** [55]	0.0678	**0.7725**	-0.1089	-0.3197
31	**I was not aware of my real environment** [55]	-0.2788	**0.6234**	0.1050	0.1294
32	**In the computer generated world I had a sense of "being there"** [55]	0.1659	**0.7270**	0.0932	-0.2845
33	**Somehow I felt that the virtual world surrounded me.** [55]	0.0869	**0.7581**	-0.0462	-0.0113
34	I felt present in the virtual space. [55]				
35	I still paid attention to the real environment. [55]	-0.1581	0.3335	-0.0337	0.4365
36	The virtual world seemed more realistic than the real world. [55]	0.1987	-0.2408	0.2188	0.4189
37	I felt like I was just perceiving pictures. [55]	-0.1309	0.2200	0.0930	0.2087
38	**I was completely captivated by the virtual world** [55]	0.1879	**0.6168**	-0.1479	0.1497
	SS loadings	5.7679	5.2017	3.6219	3.2270
	Proportional Variance	0.1696	0.1530	0.1065	0.0949
	Cumulative Variance	0.1696	0.3226	0.4292	0.5241

4.2 Questionnaire Design

Following the insights gained by the literature review on motivation for attending performing art shows, and on the factors that influence the user perception of VR experiences, we decided to design a questionnaire that would incorporate aspects related to *Cognitive, Affective* and *Spiritual* engagement to the opera and the VR lobby, as well as *Presence* and *Immersion* in VR environments. The selection was done to allow us to assess the user experience of our participants along the main axes that guided our design process [28]. Thus, it would help us gathering insights on how the VR lobby contributes to the fulfillment of the main goals of theater lobby experiences, while analysing the aspects that most contribute to an immersive VR experience [58]. Spir-

itual engagement refers to connectedness with self, others, and a larger reality [48], motivated by the audience's need for escapism as well as aesthetic pleasure, contemplation, and wonder. Emotional (or affective) engagement refers to the need to be moved, experience the past, and have a sense of cultural identity, and is usually measured in terms of what emotions were elicited by the experience [22]. Intellectual (or cognitive) engagement is linked to the desire for self-improvement, as well as personal interest; it is measured by considering the level of interest and curiosity that the experience caused [22]. Similarly, subjective enjoyment and behavioral intention to experience again have often been used in studies to understand the level of satisfaction of the users with the experience [11, 29, 40, 67].

To measure *Immersion*, we combined and adapted three items from the Immersion scale and two items from the Person-Virtual Environment Interaction scale from [20]. IPQ questionnaire (14 items) [55] was used to measure the level of *Presence*. The scale to measure *Affective* (6 items) and *Cognitive Engagement* (3 items) was selected from the original scale [22]. The *Spiritual Engagement* was measured by combining two items from [48] on the spiritual engagement and three items from [63] on the spiritual motivation of theatre-goers.We also asked the participants about their evaluation of the opera, including their Subjective Enjoyment (3 items) [29] and Behavioral Intention to watch the VR opera again and to recommend it to friends (2 items) [67]. All the items used in the validation can be found in Table 1; they were administered after the VR experience, on a 7-grade Likert scale. The items were purposedly selected from existing literature as their validity in evaluating the aforementioned concept has already been tested in VR scenarios related to entertainment and education. Finally, as control variables, we measured people's level of comfort when using VR via a Simulator Sickness Questionnaire (SSQ) [24], both before and after the VR lobby experience.

4.3 Experiment Setup and Procedure

4.3.1 Participants and setup

This second study was conducted from September 26th to October 28th, 2022. We ran a between-subject controlled study comparing an individual (N=20) and pair (N=20), as a within-subject study would cause novelty issues (both for the opera and lobby) and affect the length of the experiment. We conducted a power analysis with the software program G*Power [13], with the goal of obtaining .8 power to detect a large effect size of 0.8 at the standard 0.05 alpha error probability. Thus, we designed the experiment to be run with 20 participants per condition, resulting in 20 individuals and 10 pairs (theoretical power > 0.78 with 20 participants per unmatched pair). Participants were recruited via flyers - in the CWI building-, and postings on social media channels. Participants were of diverse ages (m=33.05, sd=12.84), gender (M=27, W=13), jobs (student, scientist, artist, librarian, etc.), and experiences in VR (none=7, novice=21, knowledgable=7, expert=5). Paired participants already knew each other. For individual-participant sessions, one researcher conducted the study; for paired-participant sessions, two researchers conducted the study simultaneously in two separate VR rooms. Each session lasted approximately 40 min to 1 hour, depending on the number of participants (individual and pairs) and their level of enthusiasm. The compensation was 10 euros voucher.

4.3.2 Technical setup

The technical setup was the same as 3.2.2. In this second experiment, the position and rotation of the camera associated with HMD of each participant were also recorded, together with the timestamped data, in order to analyse the navigation movements of both individual and paired participants.

4.3.3 Procedure

At the start of the experiment, researchers gave a short introduction to the study and asked participants to sign the consent form and fill in the demographic and VR sickness questionnaire. The study consisted of three steps:

Step 1: Participants individually watch digital opera (9 min). This step was identical to Step 1 in Part 1 (3.2.3).

Step 2: Participants explore the Social VR Lobby (alone OR together) (10-20 min). After watching the opera, participants were sent to the social VR Lobby from the cinema room without a break. The researchers asked participants to stand up and then handed them over VR controllers; in VR, the participants' point cloud representations were enabled. Participants started the experience at the Training zone, where they were taught three interaction methods - teleport, grab, and button clicks. After the training, they were asked to freely explore the VR lobby with no particular sequence. Unlike the previous experiment, we did not request participants to use the 'Think-aloud' method.

Step 3: Participant(s) individually answer questionnaire & semi-structured interview (10 min). After participants fully experienced the lobby, they took off the VR headset and finished the remaining questionnaires. Thereafter, the researchers individually conducted a semi-structured interview with participants and voice-recorded the entire conversation.

5 Results

5.1 Quantitative Results

5.1.1 Exploratory Factor Analysis

To understand the underlying factors in the questionnaire we administered to the users, we performed Exploratory Factor Analysis (EFA) on the responses [10]. EFA is a classical formal measurement model that is used when both observed and latent variables are assumed to be measured at the interval level [14]. Latent variables are commonly called factors, and the association between observed and latent variables is called factor loading. We chose EFA as we did not want to impose any preconceived notion of factors on the data we collected, rather looking for insights into the data. To test whether the data allowed for EFA, we ran Cronbach's α to measure reliability, Bartlett's Sphericity test, and Kaiser-Meyer-Olkin (KMO) test for sampling adequacy. Results showed high reliability ($\alpha = 0.9428$), and the null hypothesis of sphericity was rejected at 95% significance level ($\chi^2 = 1629.53$, $df = 703$, $p < .001$); however, KMO values did not allow for EFA ($kmo = 0.1443$), due to high correlation between items in the questionnaire. Thus, we decided to remove items whose correlation with another item in the questionnaire was above 0.8. Items 10, 21, 26, and 34 in Table 1 were removed from the analysis, resulting in high reliability ($\alpha = 0.9309$), no sphericity ($\chi^2 = 1070.41$, $df = 561$, $p < .001$), and a KMO value above the 0.5 recommended threshold for EFA ($kmo = 0.5971$).

We ran EFA using maximum likelihood estimate with oblique rotation, and we used the goodness-of-fit criterion to decide on the number of factors: the null hypothesis corresponds to the EFA model perfectly fitting the data. The null hypothesis was rejected for one ($\chi^2 = 734.53$, $df = 527$, $p < .001$), two ($\chi^2 = 636.66$, $df = 494$, $p < .001$), and three factors ($\chi^2 = 527.71$, $df = 462$, $p = 0.0184$), while it failed to be rejected for four factors ($\chi^2 = 458.39$, $df = 431$, $p = 0.1745$), with good goodness-of-fit ($RMSEA = 0.0404$). Thus, we employ four factors in our analysis. The factor loadings for each item in the questionnaire and each factor are shown in Table 1. The explained variance of the four factors is 52.41%.

Following standard practices in the literature, we consider only items that load on one factor with a magnitude of at least 0.4, and with a difference in cross-loadings of at least 0.2 [19, 31]. The items fitting the criteria are highlighted in bold in Table 1. We mapped the factors into 4 concepts, and computed their internal reliability: **Engagement** (Factor 1, 9 items, $\alpha_1 = 0.9240$); **Immersion and Presence** (Factor 2, 10 items, $\alpha_2 = 0.8529$); **Connection to Performance** (Factor 3, 4 items, $\alpha_3 = 0.9215$); **Realism** (Factor 4, 3 items, $\alpha_4 = 0.8636$). In our subsequent analysis of the results we refer to the four factors. The 26-item questionnaire with each response scale is available in the supplemental materials.

5.1.2 Questionnaire Response Analysis

Figure 4 depicts the violin plot of the answers to the questionnaires for each of the factors found through EFA, namely, Engagement, Immersion and Presence, Connection to Performance, and Realism), sep-

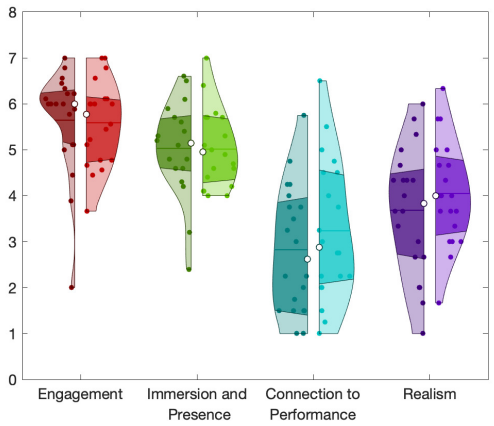

Fig. 4: Violin plot of the results from the quantitative analysis for both individual (left side) and pair participants (right side).

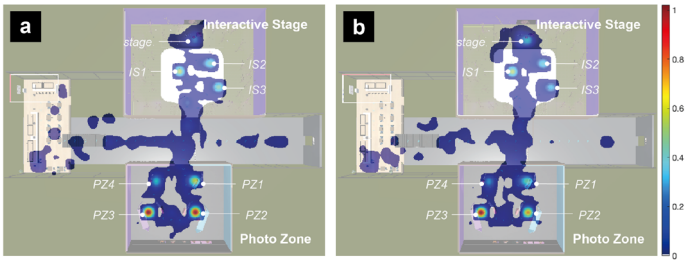

Fig. 5: A floor map of the VR lobby with the user heatmap of the main location visited over time by participants as (a) individual and (b) pair.

arately for single users (left-side, darker color), and pairs (right-side, lighter color). Note that, since each factor has a different number of items, we chose to average the values instead of simply adding them; hence, each factor has a min value of 1 and a max value of 7, per the Likert scale. The median value for each item is depicted as a white dot in the center, whereas the mean value is depicted as a darker horizontal line.

Generally, we can observe high values for Engagement ($M_s = 6$, $M_p = 5.778$) and for Immersion and Presence ($M_s = 5.15$, $M_p = 4.95$), for both single and paired users. The values for Connection to Performance are more spread throughout the scale, with a low median value for both single and paired users ($M_s = 2.625$, $M_p = 2.875$). The Connection to Performance, as we assessed it, is very linked to the opera performance itself and to the connection the user has to its content; this makes it both a very personal matter and a difficult parameter to quantify, which explains the breadth of our recorded answers and its low median value. Different opera contents might appeal more to users, or give a deeper connection. Nonetheless, this is an important parameter that will inform our future choices both in designing future experiences and evaluating them in a more effective way. Finally, we observe medium-low values for Realism, for both conditions ($M_s = 3.833$, $M_p = 4$). The relatively low values for Realism are not surprising, considering that the VR lobby was not constructed with realism in mind: our intention was not to create a world that would "seem real" (see question 29), but rather a low-fidelity representation of the opera world that would encourage interaction and participation from the users, while still being lightweight. It is notable to see that lower values of perceived realism do not seem to affect the level of presence and immersion experienced by the participants. To further investigate the aspect, we ran Pearson's correlation coefficient between the Realism items and Immersion and Presence items; results are not significant for single users ($\rho = 0.2716, p = 0.2468$), whereas they are for pairs ($\rho = 0.5850, p = 0.0067$). Further analysis is needed to determine how much the social aspect of VR experiences influences the interplay between the factors.

To check if statistically significant differences could be found between single and paired users for any of the factors under consideration, we ran a two-tailed Mann-Whitney U-test, after ascertaining the non-normality of the distributions with a Kolmogorov-Smirnov test ($p < 0.05$ for all factors). No statistical difference between single users and pairs is observed at the 95% significance level for any of the factors under test (Engagement: $z = 0.5708, p = 0.5682, r = 0.0902$; Immersion and Presence: $z = 0.5422, p = 0.5877, r = 0.0857$; Connection to Performance: $z = -0.8816, p = 0.3780, r = 0.1394$; Realism: $z = -0.6923, p = 0.4887, r = 0.1095$).

5.1.3 Simulator Sickness Questionnaire

The SSQ was administered before and after the VR experiment, as suggested by the literature [6], and factors Nausea, Oculomotor disturbance, Disorientation, as well as the total score, were computed according to the original work [24]. Values for Nausea are minimal before the test ($N = 8.82$), turning significant after the test ($N = 12.16$); for Oculomotor disturbance, they are significant before the test ($O = 14.21$), and they become concerning after ($O = 18.95$); for Disorientation, values are concerning before the test ($D = 16.36$), with a marked increase after ($D = 26.80$). The total score before the test is equal to 147.33, whereas, after the test, it increases to 216.58.

5.2 Navigation Behavioural Results

The navigation analysis is based on the recorded logs collected during experiments as described in Section 4.3.2. For the following analysis, the data was resampled at 30 Hz and we excluded users' movements inside the training zone to avoid any misleading results due to the presence of the instructor.

A general overview of the navigation behaviour of participants is given in Figure 5, which shows a heatmap of the most visited location in the virtual lobby for both participants who ran the experiment individually (Figure 5(a)) and in pair (Figure 5(b)). The most visited locations, or where users liked to spend most of the time, correspond to the different interaction points within both the Interactive Stage and the Photo Zone. In particular, the favourite locations are the two photo machines in the photo zone (PZ2 and PZ3 in Figure 5), as highlighted by the strong red spots near these interaction points. To be noted is also that single participants spent more time exploring different areas of the VR lobby (see larger blue areas in the bar in Figure 5(a) in contrast with Figure 5(b)). Overall, participants who took part in the experiment alone spent on average 9 minutes exploring the VR lobby, of which 3 minutes inside the Photo Zone and almost 5 minutes in the Interactive Stage. Instead, coupled users spent on average 12 minutes in the VR lobby, 5 minutes on average within the Photo Zone, and 6 minutes in the Interactive Stage. These observations reflect the high level of engagement detected by the questionnaire in the previous section.

Figure 6 displays the violin boxplot comparison between the percentage of motion exhibited by each participant, both individual and paired. Following the behavioural analysis in [51], we considered the user to be moving if their relative position at each time step changed more than 0.05 cm, or if any of their rotation angles varied by more than 0.01 rad. It can be noticed that most of the interaction happened inside the photo zone and interactive stage for both single and paired participants. This observation confirms that users not only spent most of the time within these rooms, as shown in Figure 5, but they were also moving in these spaces. Generally, we can notice that the values of interaction for paired users are more spread and higher in the entire experience, in contrast with individual participants.

Finally, we further analysed the interaction among the paired participants by evaluating their pairwise distance (in terms of Euclidean distance) over time in the entire experience in the VR lobby. Figure 7 shows the histogram of the probability distribution of the pairwise distance between users in pairs. To evaluate the proximity and personal space in the VR lobby, we also indicated Hall's proxemic zones [16].

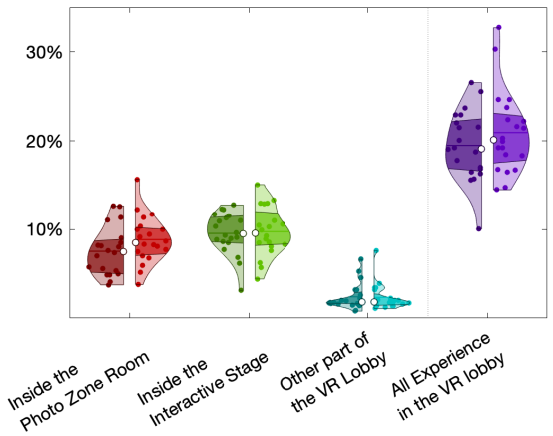

Fig. 6: Violin plot of users' motion based on both spatial and rotation movements in the different rooms of the VR lobby for both individual (left side) and pair participants (right side).

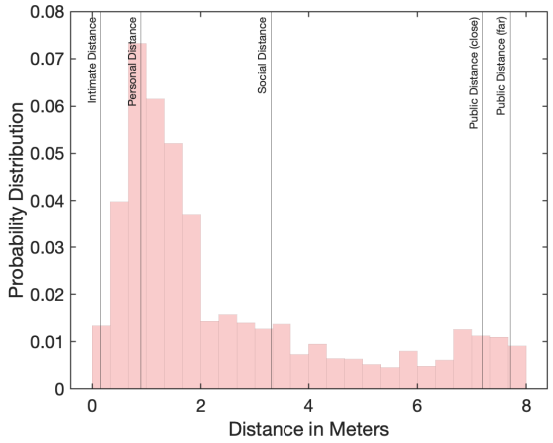

Fig. 7: Histogram of the probability distribution of the pairwise (Euclidean) distance between paired participants. The proxemic zones [16] are also labeled on the x-axis.

It can be noted that participants, who already knew each other, as mentioned in Section 4.3.1, spent most of their time together while exploring the VR lobby. In particular, they were within the *personal* and *social* distance zones, respectively between 0.45-1.2 meters and 1.2-3.6 meters.

5.3 Qualitative Results

We follow a similar procedure presented in Section 3.2.4 for the analysis of the 40 interview audio recorded in this second study. Individual participants are labeled P1-P20, and paired participants are labeled P1a/b-P10a/b. In parenthesis, we indicate how many participants agreed with the given statement.

5.3.1 Perceived values of the social VR Lobby

The benefits of the social VR lobby are grouped into three sub-themes: **Connecting and sharing the experience with others (Social).** Participants (6) valued that they could discuss what they have seen in a remote setting *(P4: "You've all watched the opera and have this shared experience. You normally would have a drink at the bar after some event. That it makes it possible to have that interaction still, even though you're in the virtual space.")* Seeing the point cloud representation of others, not an avatar, added benefit when connecting to each other (7) *(P2a: "... just to be able to know that it's [partner], and not an avatar was different because I know how my friend behaves. They are real nuances of his movement. It felt more very much present.")*

Immersive opera experience (Opera). Participants (7) mentioned that the lobby helped them consume and understand the opera on a deeper level *(P4a: "I could really be immersed in the world of the content...")*. Some participants (5) deepened the experience through imagination *(P11: "I like changing the bench, stage, background... I got a lot of imagination and different storylines for those settings")*, and some (5) valued getting a more personal experience *(P10: "So, it gives you a feeling that you actually experience the opera itself. It's not like you're an outsider watching.")*

Free from realistic constraints (VR). Participants (8) found the VR Lobby had less time, money, and geographical constraints, as people who are *'not physically able to either go to or afford the actual opera,' 'patients,'* and *'a family living elsewhere'* can still enjoy the experience by *'not having to travel halfway across the world'*. Participants (8) stated that it expanded the range of performable interactions, *(P7b:"... we can take pictures or grab stuff like a hat or an umbrella... We cannot do this stuff after watching the opera. But in the virtual world, we can actually enjoy more than the reality.")*

5.3.2 Interaction behaviors and patterns

Enjoying interaction with others. Even though no statistical difference was found in quantitative measures between individual and paired participants' experience (Sec 5.1.2), most participants across both groups (70%) mentioned that they would prefer a together experience, and only three participants (7.5%) desired to visit the VR Lobby alone. Participants (12) with paired experience appreciated the interaction with their partners, mentioning that they enjoyed *controlling settings, seeing the changes,* and *being silly 'together'* with their partner. Some (5) even stated that the experience would have been boring if they were doing interaction alone.

Amused finding out possibilities. Participants (21) tried pressing all the buttons and grabbing the (even the background) objects to see what effects they could bring. They were proud of themselves for finding out the new features *(P9: "I enjoyed the most taking a prop with me, grabbing it, and posing with it, and taking pictures. (...) And I was proud that I managed to discover how it [the hidden feature] works."*

Willing to have control over own interactions. Participants (21) regarded simple and basic control interactions as their most enjoyable interactions, such as *picking up items, walking with holding objects, stacking blocks,* and *pressing buttons.* This characteristic aligned with their navigation pattern (Sec 3.3.2) - the easy completion of tasks gave them satisfaction from having complete control over their actions.

5.3.3 Suggested improvements to the social VR Lobby

Interactions to booster social engagement. While the current interaction activities were designed for both single and multiple users, some participants (paired: 9, solo: 7) found the interaction activities still *passive* and could be improved for a deeper social engagement by assigning roles *(P2a: "... The experience is dependent on you have this role (...) and we're complementary... ")* or through cooperative tasks *(P7a: "...cooperate with their friends to finish some games").*

Interactions for a deeper engagement with the opera. Participants (8) mentioned a weak connection between the opera and the interactions in the VR Lobby, that experience was *'too focused on the interaction'*, and thus *'more concepts related to the opera'* or *'information combined with the interaction'* were needed. Participants (10) desired deeper engagement with the opera via activities, such as *'access to backstage view', 'extra gamified interactions', 'record self-reflection',* and *'interact with real actors'*.

6 Discussion

6.1 Limitations

Naturally, this work involved several limitations, which will guide future work of the community. First, we focused only on the 'after-watching experience', whereas the lobby could also be a place to connect and raise the excitement towards the play before watching. The opera watching is not segmentable, but rather a collective journey of experience. Second, given our controlled study, the participants could not choose which opera to watch. The lack of interest in the contents of

the opera may have influenced the general experience in the social VR Lobby and the level of interaction between partners, as proven by the relatively low values in the *Connection to Performance* factor. Finally, we only compared individual and paired participants - who knew each other -, while the experience would vary for the number of crowds, the relationship between them (friends, strangers, family), etc. For example, having intelligent agents populate the space would change the way users experience the lobby. In the future, we aim to explore how social density and different group configurations can change the user experience in the VR lobby, and we will measure them by explicitly including social engagement aspects in our evaluation.

6.2 Mixed-method analysis, and the value of the social VR lobby

In Part 1, our goal was to create a VR lobby with *four* rooms that enhance the social remote opera-watching experience, based on *four* primary motivations of theatre-goers identified in the literature. Our research revealed that the audience's engagement cannot be measured separately for each room, as it is a collective and cumulative experience. This aligns with our initial premise that the 'lobby' enhances the overall opera-watching experience. Thus, in Part 2, we revised the lobby design and conducted a controlled study to compare the experiences of individual and paired participants to test if the VR lobby enhances the social experience in remote opera-watching. The study's multifaceted analysis, encompassing EFA, questionnaire, navigation behavior, and interview analysis provides valuable insights into the Social VR Lobby's impact on participants' experiences. Participants' questionnaire responses did not show any statistical difference between single and paired individuals in terms of the four identified factors - *Engagement, Immersion and Presence, Connection to Performance*, and *Realism*. However, their navigation behavior revealed that paired participants, on average, spent more time and had higher interaction in the lobby, and also spent most of their time with their partner within the personal and social distance zones. Likewise, the interview analysis highlighted the benefits of experiencing the VR lobby together, interacting with others, and commenting on the performance. The mixed-method approach we selected for the study proved to be crucial in gaining a deeper understanding of the user experience, which would not have been possible by using questionnaires alone. Still, further work is needed to better understand the added value of socially experiencing VR spaces and how it influences factors such as immersion, presence, and engagement.

6.3 Immersion, Presence, and Realism

In our choice of items to be added to our questionnaires, we identified Immersion and Presence as two key factors to be evaluated in VR experiences. In the original questionnaires, factors that were identified included *Immersion*, *Person-Virtual Environment Interaction* [20], *Spatial Presence*, *Involvement*, and *Experienced Realism* [55]. However, in our analysis, two separate factors emerged: **Immersion and Presence** - partly encompassing *Immersion*, *Person-Virtual Environment Interaction*, *Involvement*, and *Spatial Presence* - and **Realism**, partly covering *Experience Realism*, and partly covering *Immersion* from previous questionnaires. Some items were removed as they loaded on both factors (e.g., item 5, 35, and 36 in Table 1), suggesting that depending on the question wording, an interplay between the concepts might be captured. However, analysis of results showed that Realism and Immersion and Presence might not be necessarily correlated; in fact, results for the two factors are statistically different at 95% significance level (Wilcoxon's test: $z = 4.7107$, $p < .001$, $r = 0.5267$), with a large effect size. Thus, a low value of realism might not necessarily impede participants from feeling immersed in the virtual environment, as postulated in other works [21, 65]. We did notice, however, that results were differing when comparing single users with respect to paired participants, the latter exhibiting a significant correlation between factors Immersion and Presence, and Realism. For paired users, the contrast between the photorealistic representation of the other user and the low-fidelity realism of the environment might have played a role in how immersed they felt - a factor that's been observed in previous literature [61]. Further work is needed in analysing and ascertaining how the mixture of styles and modes might affect the users' perception in virtual spaces.

7 Conclusion

This paper presents the design, implementation, and evaluation of a social VR lobby for enabling social interactions after experiencing a virtual opera performance. Specifically, we conducted an initial test with experts to validate our social VR lobby, developed based on theoretical concepts addressing high-level audience motivation: *social*, *intellectual*, *spiritual*, and *emotional*. After refining the lobby for improved usability and user experience, we conducted a between-subject study to compare individual and paired user experiences in our social VR lobby across three aspects: questionnaire, user behavior, and interview analysis. A questionnaire was designed and validated to properly assess the VR lobby experience, covering *cognitive, affective*, and *spiritual* engagement with the opera and the VR lobby, as well as *presence* and *immersion* in VR environments. Overall, our mixed-methods analysis reveals the strength of our social VR lobby as an extension of a remote opera performance, with results showing high levels of engagement, immersion, and presence for both individuals and pairs. Future work will focus on further validating the proposed questionnaire, improving the design of the VR lobby according to the feedback collected in the interviews, and considering aspects such as connection to performance and cybersickness, as well as testing the design with different use cases.

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