A Comparison of Behaviours and Responses towards Different Social VR Environments in Initial Social Interaction

Seung Jin Chung[1], Hyun-jae Jo[2], Hyunju Lee[3*]

[1]Department of Human Environment & Design, PhD candidate, Yonsei University, Seoul, Korea
[2]Department of VR Game Contents, Associate Professor, Shingu College, Seongnam, Korea
[3]Department of Human Environment & Design, Professor, Yonsei University, Seoul, Korea

Abstract

Background Despite the significant level of recent interest in social virtual reality (VR), there has been little discussion about environment design considerations that affect social interactions. This study suggests two possibilities for environment design in social VR. One is reality-based worlds where the definition of place is obvious, and the other is virtuality-based worlds where the definition of place is ambiguous. This study aims to explore environment roles in social VR by comparing behaviours and users' responses in the two environments, with a focus on the early stages of social VR.

Methods This study collected data from 46 research participants who were assigned to a team and arranged in a virtuality-based or reality-based environment setting. In order to explore initial social interactions, data of exploration and meeting sessions were collected. The differences in behaviour, according to their environment, were compared based on the coding scheme via video recording. For qualitative analysis, a contextual interview was held to understand affective responses by the given environment and the environmental factors influencing behaviours.

Results As a result of the behaviour observation analysis, specific behaviours were prominent according to the provided environment designs in the early stages of social interactions. Significantly, we found that the behaviour of gazing at other participants (S_HeD) was significantly higher in the virtuality-based environment, and the behaviour of manipulating objects (In_Obj) was prominent in the reality-based space during the exploration session. On the other hand, the gap in behaviour decreased during the meeting session. As a result of the interview analysis, it was revealed that the virtuality-based environment indicates freedom to users, while the reality-based environment provides familiarity.

Conclusions This research contributes to exploring the design possibilities and considerations through user data analysis of the different social VR environments. The study illustrates the importance of environment design in social VR and showes that the design can induce specific behaviours according to its contextual meaning. Also, social interactions can be motivated depending on how users affectively accept the environment. Understanding the role of environment design is significant for successful social VR functioning.

Keywords Metaverse, Social VR, User Experience, Virtual Environment Design, Virtual World

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*Corresponding author: Hyunju Lee (hyunju@yonsei.ac.kr)

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1. Introduction

Social virtual reality (VR) has only recently captured the attention of such industries as entertainment, business, and education. The research on social VR can be traced back to work on collaborative virtual environments (CVEs) (Freeman & Maloney, 2021; Jonas et al., 2019). Computer-supported cooperative work (CSCW) and VR technologies aided the development of CVEs, and both social VR and CVE studies facilitate social interactions as much as face-to-face contact (Benford et al., 2001). However, it may well be difficult to consider them synonyms because CVEs encompass a broader spectrum of virtual environments ranging from three-dimensional immersive environments to 2.5D, 2D, and text-based environments (Snowdon et al., 2001). Meanwhile, social VR is primarily focused on the immersive experience, generally provided by head-mounted displays (Baker et al., 2020; McVeigh-Schultz et al., 2019). This study defined social VR as an immersive three-dimensional space where people can meet, interact, and create together using immersive VR devices.

Despite the significant level of recent interest in social interactions in a virtual world, there has been little discussion about environmental design considerations in this domain. The social VR environment, a visually rendered three-dimensional virtual space, is an important factor in determining the social frame (McVeigh-Schultz et al., 2019) as it affects individual behaviour and the quality of experience (Burgoon et al., 2016). For example, architectural elements can facilitate or regulate social interactions by establishing a sense of place and inducing specific social behaviours in a given setting (Patterson & Quadflieg, 2016).

Additionally, virtual space has been generally implemented to resemble an actual physical environment, where users interact in a manner comparable to the real world through avatars. However, not all virtual worlds are direct imitations of the real world (Bowman & Hodges, 1999), and it is worthwhile to examine a virtual environment that does not reflect the real world. Thus, this study explores two possibilities for environment design in social VR: reality-based worlds where the definition of place is obvious and virtuality-based worlds where the definition of place is ambiguous. The aim of this study is to explore how each environment plays a role in social VR, especially in the early stages of social interaction by comparing nonverbal behaviours and users' responses in the two different environments.

2. Literature Review

2. 1. Social VR

Social VR is an immersive three-dimensional space where people can meet, interact, and create together using immersive VR devices. It is a virtual world related to the concept of the metaverse. 'Metaverse' is a portmanteau of 'meta' (meaning 'beyond, virtual') and 'verse' (shorthand for 'universe') (Dionisio et al., 2013). Metaverse was introduced by Neal Stephenson, in his science fiction novel Snow Crash in 1992. For a long time, it remained a

concept without successful implementation because of technical limitations (Davis et al., 2009; Ondrejka, 2004). However, in recent years, advanced technologies, such as VR, mixed reality (MR), artificial intelligence (AI), and blockchain have converged into the concept of the metaverse. Consequently, today's metaverse has been presented with feasible possibilities in various sectors such as society, education, and business (Díaz et al., 2020; Jeon et al., 2022) as a fully immersive three-dimensional digital environment (Dionisio et al., 2013). To achieve the ideal of the metaverse, real-time interactivity (Nevelsteen, 2018) and user creation (Davis et al., 2009; Ondrejka, 2004) are required. Similarly, the ultimate goal of social VR is to create new value within a virtual world. Users can construct values in social contexts. Objects created from raw materials can become exceedingly valuable because of users' time and effort, and their worth is determined by the market (Ondrejka, 2004). To achieve this, prerequisites such as social presence (Yassien et al., 2020), social interaction (e.g., intimate conversation) (Moustafa & Steed, 2018), and interpersonal trust (Mütterlein et al., 2018) are required. Furthermore, the provided environments are expected to contribute to establishing specific social contexts.

2. 2. Environment design in Social VR

Environment design is significant to social VR design, which is challenging as it considers several trade-offs in different contexts. While the number of social VR applications has increased significantly in recent years, the state of social VR design has become more obscured, making it more difficult to identify adoption-worthy design trends, best practices, and features (Gunkel et al., 2018; Jonas et al., 2019). Existing research shows that virtual environment design (scene or place) is important in determining the social frame (McVeigh-Schultz et al., 2019). In the real world, attractive places positively affect experience quality (Burgoon et al., 2016), and architectural features influence social interaction (Benford et al., 2001; Gebhard et al., 2019; Patterson & Quadflieg, 2016). Similarly, in virtual worlds, creativity can be fostered (Fleury et al., 2021) and people can engage in more social interactions according to the way simulated environments are designed (Tanenbaum et al., 2020; Yassien et al., 2020).

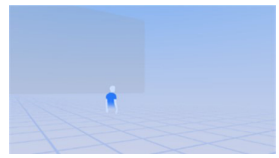
2. 3. Social VR environment types

Virtual environment simulation can be divided into virtuality-based and reality-based environments, related to the ontology of VR (See Table 1). The term VR is paradoxical by compounding the two words, 'virtual' and 'reality' (Strate, 1999). The virtuality-based environment is associated with the concept of paraspace. The term 'paraspace' was first used by science fiction author Samuel R. Delany to describe a space in which the forms or laws of natural and social relationships differ radically (Bukatman, 1992). This imagined space can be produced by inverting, abstracting, or contradicting ordinary environments (Burrows, 2020). This aesthetic approach is related to futurism, abstract art, and constructivism (Mura, 2007).

The reality-based environment is focused on accurate representation rather than imagination. A virtual world that presents a reality environment has a positive effect in that it eliminates the cost and risks of the real world. This environment type can be used for simulation (Heydarian et al., 2015) or therapeutic purposes (Flobak et al., 2019, García-

Batista et al., 2020). Also, users can have the experiences they wish they could enjoy in the real world, such as travelling. This aesthetic approach is related to realism or hyperrealism (Kullmann, 2014). As indicated in Table 1, two distinct approaches to environment design can be suggested, which have significantly different denotative and connotative meanings, and little is known about how these distinctions affect user experiences. Additionally, these two types of environment design can be presented as a spectrum concept, as seen in Figure 1. The spectrum can include other design possibilities, such as the less familiar reality-based space or the less abstract virtuality-based space.

Table 1 Social VR environment types

Types	Virtuality –based	Reality–based
Characteristics	fictional/imaginary/unrealised	realistic/ordinary/realised
Sense of place	undefined	defined
Denotative meaning	abstract space	familiar place (e.g. auditorium, home)
Connotative meaning	freedom	limited with rules
Example (Source: Spatial)		

3. Methods

3. 1. Research design

We designed an experiment to compare the differences between the social VR environment types. This study focuses on the initial social interactions when entering a social VR platform to explore the role that each environment which plays during building social relationships prior to collaboration. Environment designs were selected through a social VR platform based on their expected characteristics (Figure 1). The virtuality-based setting was a vague space, like a vacant dome; the reality-based setting was a meeting room with a table. These two settings are surrounded by walls, as though they were indoor spaces. However, they were recognised as different spaces. To explore the role of each environment, behaviour observation by video recording and one-to-one interviews were adopted as qualitative research approaches.

The study hypothesises that specific behaviour types could be shown differently according to environment designs. Nonverbal communication, such as facial expressions, posture, and body movement, includes more information than verbal communication, and is considered accurate and trustworthy due to its spontaneous and uncontrolled characteristics (Burgoon et al., 2016; Frank, 2016). This study collected nonverbal behaviour data which can be observed by avatar representation. Also, after the experiment, contextual interviews were conducted and the collected interview data was analysed by the thematic analysis process.

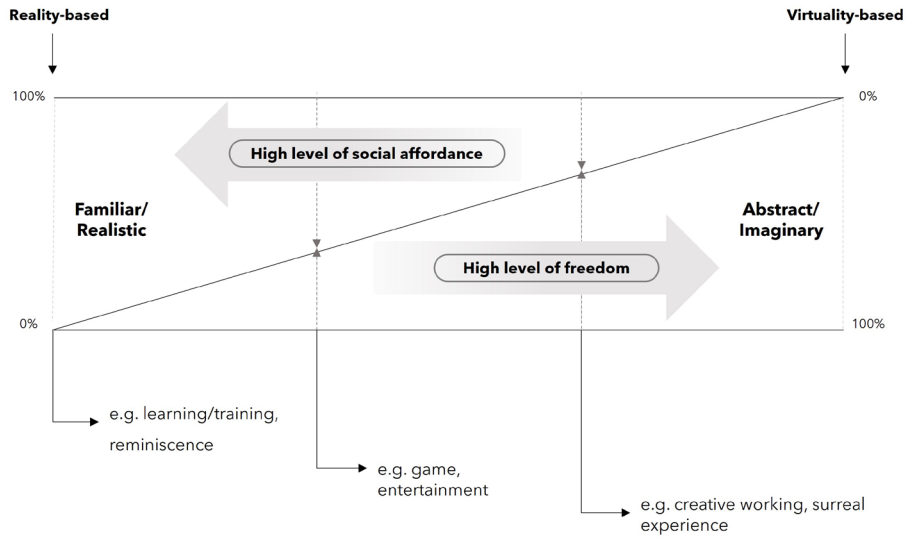


Figure 1 The social VR environment design spectrum

3. 2. Settings and procedure

The Oculus Quest was used as the chosen VR device, and Mozilla Hubs was chosen as the social VR platform as it is a closed platform and well-suited for a control. It also provides a creation menu to lead various tasks with participants and supports various devices, including desktops and head-mounted displays. The two environment conditions used in the experiment were selected among scenes offered by the Mozilla Hubs platform. Consequently, the graphic style and visual fidelity of two selected scenes are comparable. A virtuality-based space was an empty dome-shaped space with a grey floor and a blue-toned ceiling.
The reality-based space was a rectangular-shaped meeting room with light grey walls and a wooden floor, with a large table in the centre of the room. There was also a marker board on one of the walls, and small flowerpots on the desk that could not be moved.

During the experiment, individuals were placed in separate physical locations to interact with each other in the virtual space. Participants were divided into groups of three or four and randomly assigned to one of two environmental settings. They signed a consent form and trained on how to use VR equipment prior to the experiment (See Figure 2). The procedure of the experiment consisted of three parts: exploration, meeting, and collaboration. This study delivers a set of data representing the early stages of social VR participation, exploration, and meeting (See Figure 2). During the exploration phase, individuals were free to wander around a space or interact with one another without being directed. Participants then got to know each other during a five-minute meeting. The meeting's objective was to acquire at least three new pieces of information from each participant. This reflects the general experience of social VR. After the experiment, the 1:1 interview was conducted.

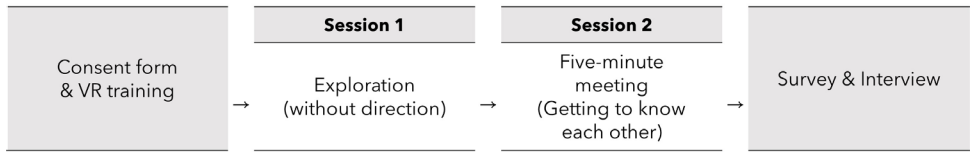


Figure 2 The procedure of experiment

3. 3. Participants

Participants who expressed an interest in VR experiences were recruited. No participation restrictions were imposed, except for being over 18 years. As shown in Table 2, a total of 46 people were involved in this study. The gender distribution of the participants was 21 male and 25 female (Virtuality-based: Male = 11, Female = 12; Reality-based: Male = 10, Female = 13), and most of the participants were in their 20s (Virtuality-based: 20s = 22, 30s = 1; Reality-based: 20s = 18, 30s = 4, 40s = 1). Most of them had no or fewer than five VR experiences. All participants had time to get used to the device before the experiment. The study was approved by the Yonsei University Institutional Review Board. Participants were recruited through the university's offline and online bulletin boards. All participants were informed and given advance notice of the details of the study (e.g., purpose, procedure, anonymous data reporting) and any risks such as dizziness that may occur owing to the VR device experience. The activity did not require a lot of movement and the total time taken was less than 30 minutes.

Table 2 Overview of participants

Case	Team ID	Participant ID			
Virtuality-based	VT1	P1	P2	P3	
	VT2	P4	P5	P6	
	VT3	P7	P8	P9	
	VT4	P10	P11	P12	
	VT5	P13	P14	P15	
	VT6	P16	P17	P18	P19
	VT7	P20	P21	P22	P23
Reality-based	RT1	P24	P25	P26	
	RT2	P27	P28	P29	
	RT3	P30	P31	P32	
	RT4	P33	P34	P35	
	RT5	P36	P37	P38	
	RT6	P39	P40	P41	P42
	RT7	P43	P44	P45	P46

3. 4. Data analysis

Coding schemes, which can be thought of as measuring instruments, just like rulers and thermometers, are central to observational methods (Bakeman, 2011). The observation was undertaken through video recording to compare nonverbal behaviours. Nonverbal cues can be observed through specific behaviours shown by avatars. This study classified nonverbal behaviour into three categories, referring to the research by Maloney et al. (2020): social behaviour, individual behaviour, and disturbing behaviour. Social behaviour and disturbing behaviour could be regarded as behaviours characterised by favourable or disagreeable social interactions. By contrast, individual behaviours are difficult to regard as having social

meaning in themselves, even though they might lead to social behaviour eventually. In this experiment, a given object does not indicate an element of an environmental design. Instead, objects were selected by a participant according to individual preferences or needs from the create menu provided by the platform. The video recorded by each participant was coded in seconds using the ATLAS software, and observed codes are shown in Table 3. On the other hand, the recorded interview data were transcribed and analysed. The dimensions of analysis were affective responses in relation to the environment and environmental factors influencing behaviour.

Table 3 Coding scheme for behaviour analysis

Category	Description	Embodied	Code
Social behaviour (favourable)	Directing one's gaze to others in order to pay attention	Head	S_HeD
	Handing something over or pointing to attract attention	Hand	S_HaP
	Waving one's hand (s) to another to socialise	Hand	S_HaW
Individual behaviour	Exploration through head movement	Head	In_HeExp
	Exploration through body movement (teleporting or walking)	Body	In_Exp
	Searching for an object	N/A	In_SrOb
	Working with an object (e.g. moving, modifying its size, rotation, and arrangement)	Hand	In_Obj
Disturbing behaviour (disagreeable)	Extensive movement, which may be upsetting to others	Body	D_BExM
	Moving too close, which may embarrass others	Body	D_ BMtC
N/A	Moving out of space	N/A	E_Oos

4. Results

The collected data were analysed according to the environment and the kind of session (i.e. exploration and meeting). Figure 3 shows the results of comparing the behaviour categories observed by the environment and converted into percentages. In the virtuality-based environment, social behaviour was more prominent, and in the reality-based environment, individual behaviour was more prominent. Table 4 shows the mean values of each participant's observed behaviour in seconds by code. The Mann-Whitney U test for comparing the groups indicate that the behaviour of handing something over or pointing to attract attention (S_Hap) and moving the body to explore space (In_Exp) was significantly higher in a virtuality-based environment ($p<.05$) as seen in Table 4.

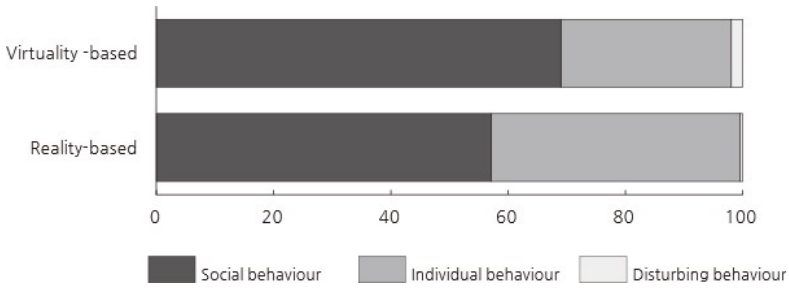


Figure 3 Comparison of behaviour categories

Table 4 Comparison of behaviour types

Variable	Type	N	M	SD	U	p
S_HeD	Virtuality –based	23	309.26	129.67	207.5	.210
	Reality–based	23	258.04	103.58		
S_HaP	Virtuality –based	23	2.13	4.72	204	**.033****
	Reality–based	23	0.09	0.41		
S_HaW	Virtuality –based	23	12.78	15.97	188	0.63
	Reality–based	23	5.70	10.43		
In_HeExp	Virtuality –based	23	25.35	24.36	207	.204
	Reality–based	23	37.26	30.60		
In_Exp	Virtuality –based	23	64.74	55.19	161	**.021****
	Reality–based	23	32.87	43.23		
In_SrOb	Virtuality –based	23	10.26	18.21	228.5	.376
	Reality–based	23	17.22	27.25		
In_Obj	Virtuality –based	23	36.30	48.95	183	.070
	Reality–based	23	108.52	123.30		
D_BExM	Virtuality –based	23	8	16.17	243	.495
	Reality–based	23	1.22	2.80		
D_ BMtC	Virtuality –based	23	1.04	4.22	264.5	1.000
	Reality–based	23	0.74	2.45		

Figure 4 presents the results of the comparison between the behaviour categories during the exploration sessions, and Figure 5 shows the same for the meeting sessions. During the exploration session, social behaviour was more prominent in the virtuality-based environment while individual behaviour was more prominent in the reality-based environment, as shown in Figure 4. During the meeting session, there was no significant difference in behaviour (See Figure 5).

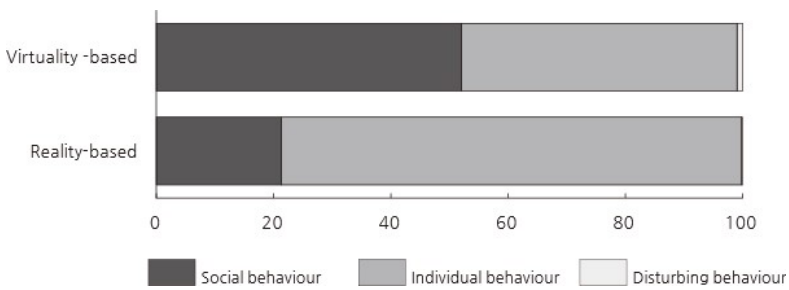


Figure 4 Comparison of behaviour categories during exploration

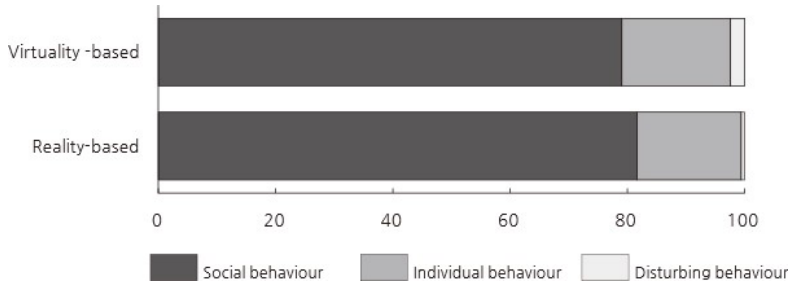


Figure 5 Comparison of behaviour categories during meeting

According to the Mann-Whitney U test results in Table 5, during the exploration session, the behaviour of gazing at others (S_HeD) was significantly higher in the virtuality-based environment ($p<.05$), whereas the behaviour of manipulating an object (In_Obj) was significantly higher in the reality-based environment ($p<.05$). In the meeting session, the behaviour of handing over or pointing (S_HaP) was found to be significantly higher ($p<.05$) in the virtuality-based environment. Figure 6 shows which behaviour is more prevalent in a virtuality-based or reality-based environment. The difference is more distinct in the exploration session than in the meeting session.

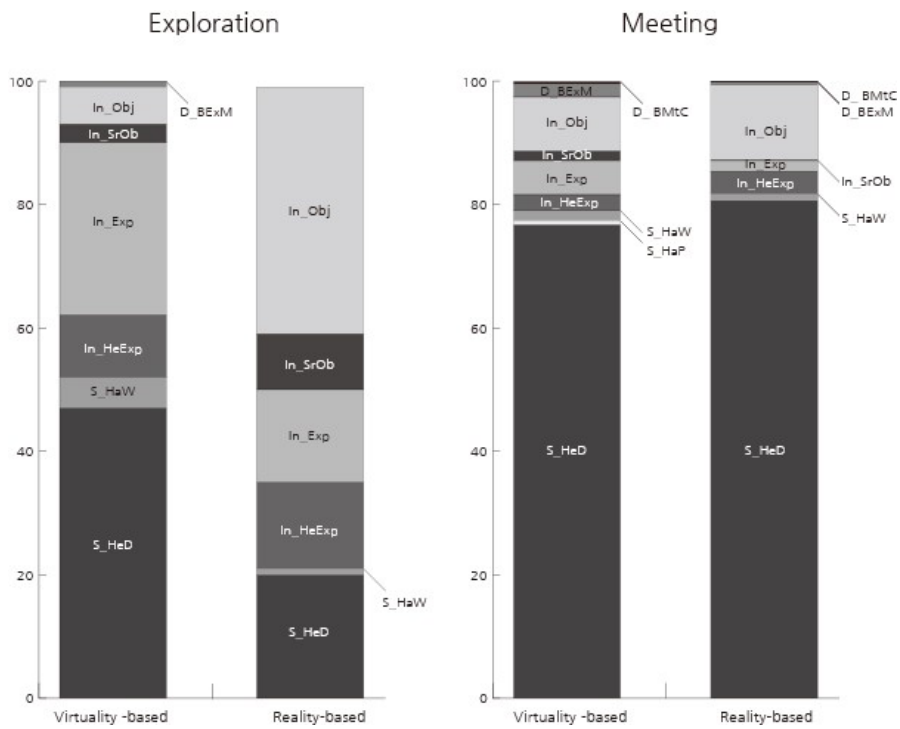


Figure 6 Comparison of behaviour types

Table 5 Comparison of behaviour types during each session

Variable	Session	U	Z	p
S_HeD	Exploration	166	−2.179	**.029****
	Meeting	260	−.099	.921
S_HaP	Exploration	253	−1.000	.317
	Meeting	195.5	−2.590	**.010****
S_HaW	Exploration	213.5.	−1.451	.147
	Meeting	213	−1.425	.154
In_HeExp	Exploration	209	−1.237	.216
	Meeting	208.5	−1.378	.168
In_Exp	Exploration	220.5	−1.009	.313
	Meeting	202	−1.648	.099
In_SrOb	Exploration	199	−1.707	.084
	Meeting	217	−1.783	.075
In_Obj	Exploration	131.5	−3.096	**.002****
	Meeting	250	−.352	.725
D_BExM	Exploration	264	−.031	.975
	Meeting	247	−.615	.538
D_ BMtC	Exploration	253	−1.000	.317
	Meeting	264.5	.000	1.000

The qualitative data from the interviews was analysed based on the thematic analysis process presented by Braun and Clarke (2006), which is an inductive analysis approach (See Figure 7). A thematic map was generated using the initial codes as shown in Figure 8, and themes were finally presented, constituting the affective responses by different environment designs and environmental factors that can affect users' behaviours. First, the virtuality-based space was mostly perceived as spacious and cold, while the reality-based space was mostly perceived as friendly and warm. Second, in the virtual environment, provided empty space was mostly considered to have positively influenced one's motivation and also enabled users to focus on others easily rather than hindering their social interactions. Conversely, participants who experienced the reality-based environment mentioned the windows as having a positive influence on exploring the space, while in the case of the table, some explained it positively, but others said that it made them uncomfortable when interacting with others.

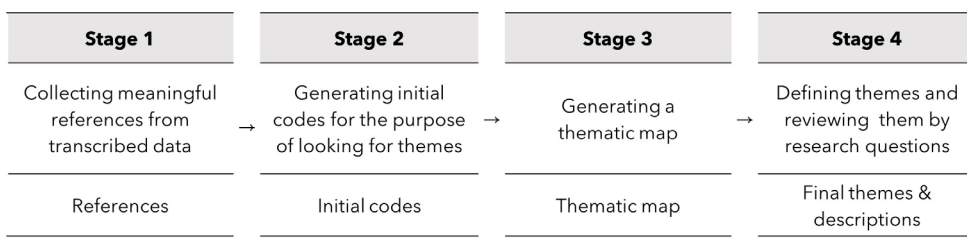


Figure 7 Applied process for thematic analysis

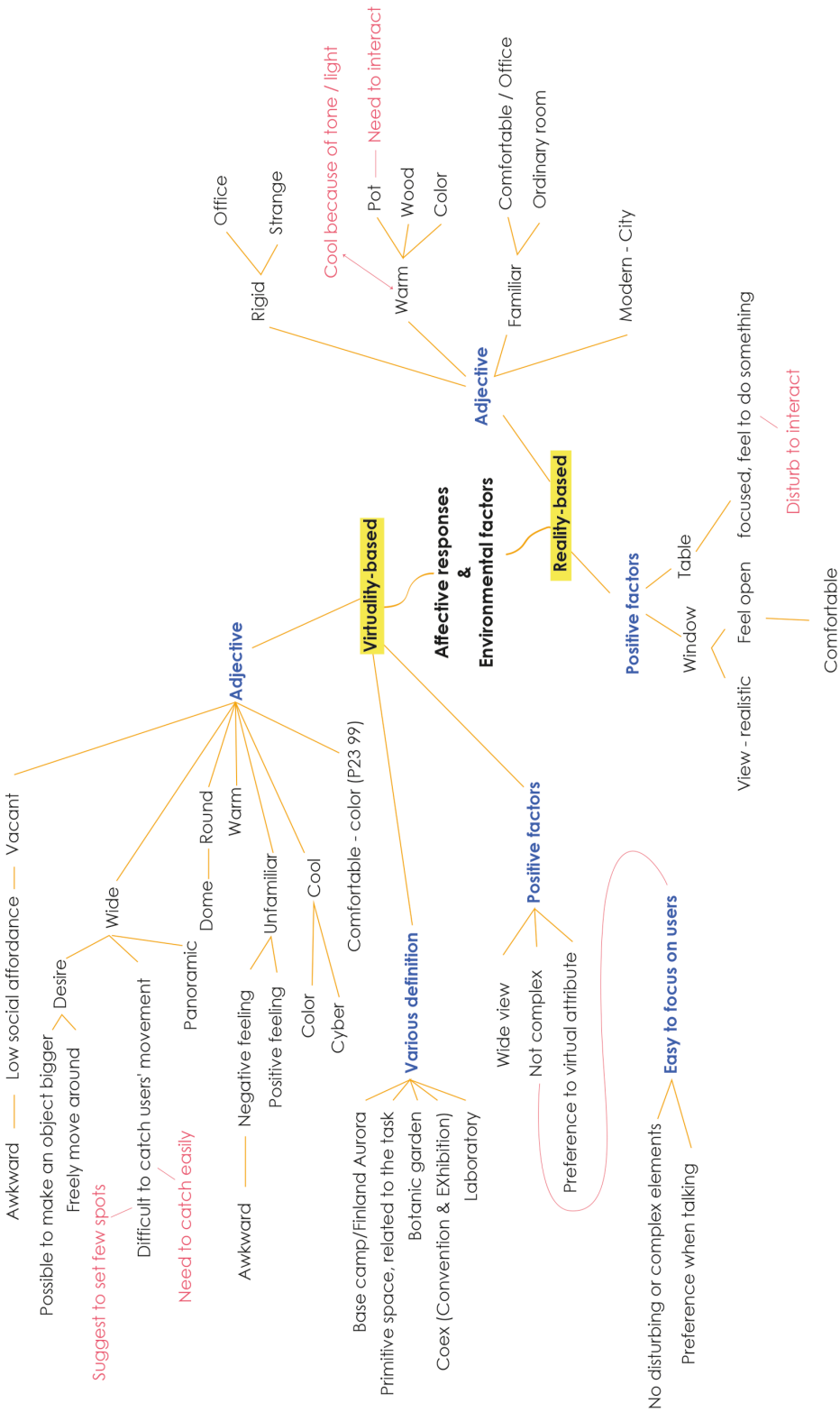


Figure 8 Thematic map for interview analysis

5. Discussion

The study compared two social virtual spaces with different meanings and figured out the following findings. First, in the early stages of the social VR experience, behaviour can be different depending on the provided environment. It found that the behaviour of gazing at other participants (S_HeD) was significantly higher in the virtuality-based environment, and the behaviour of manipulating objects (In_Obj) was prominent in the reality-based space during the exploration session. However, the gap in behaviour decreased during the meeting session. As a result of the interviews, the virtuality-based environment was regarded as a space having a high level of freedom; on the other hand, the reality-based environment was regarded as a familiar space. The infinite possibility of a virtuality-based environment, not limited by social norms or rules, is considered to trigger relatively higher social behaviours (*P12 'It felt like a different world from everyday life. I was able to focus more on conversing with virtual avatars because the area represented a virtual space rather than offices or meeting rooms'*).

Second, a virtuality-based space can be considered another positive social space. As there is no need in the virtuality-based environment to represent any specific aspects of the real world, users can be free from potential social norms. Although it might be raised the issue of whether this setting is appropriate as a social space, the interviews showed that a virtuality-based space may have a positive effect on users' unconscious motivations (*P5 'Because there was nothing in this space, I had the impression that I could do anything'*). Additionally, the vacant space aided the other person's attention (*P10 'If something had been installed, it may have distracted me, and I would have spent some time observing them. However, because it was completely empty and there was nothing there, I was able to focus on those three people for five minutes, which was satisfactory'*). This reflects a reason that the behaviour of paying attention to others (S_HeD) was higher in the virtuality-based space during the exploration session. However, at the same time, a few participants shared their experience of feeling awkward or embarrassed when faced with an empty space and were unsure of what to do (*P17 'It was so awkward because there was nothing...'*). This is related to a previous study which pointed out the importance of social catalysts in social VR (McVeigh-Schultz et al., 2019). Although the virtuality is not realised through the emptiness, an extreme virtuality-based setting may have no furniture or obstacles, and it was discovered that vacant space may encourage people to do something including social interactions. However, as participants mentioned the value of the virtuality-based environment contradictorily and also another aspect of virtuality-based environments might be suggested, more investigation is needed.

Third, in order for the objects provided in the reality-based space to accomplish their social functions, the object's purpose must be apparent. Otherwise, the object may become an obstacle. During the experiment, provided objects in a reality-based setting offered emotional stability for users (*P28 'Because of the wood floors, it seemed familiar. It seemed like a typical office space'*). However, it revealed that objects can also constrain one's activity unintentionally. For instance, a desk may help to assemble people, but also it may also drive users to the corner of a room. While some participants assessed the table as helpful (*p36 'I*

felt encouraged to discuss something because of a desk.'), others said that the table hindered communication with others (*P31 'There was a large desk in the room, and movement was constantly restricted. It was disturbing... the desk was too large.'*). The unexpected discomfort was because of its ambiguous usage such as inappropriate size. Thus, if an object is designed with the expectation of successful social interactions, users should be able to recognise and accept why and how they use the object.

Finally, the study proposes further studies based on the findings and limitations of this study as follows. First, the study simply separated virtuality-based and reality-based spaces in the experiment. However, a follow-up study that classifies the environment design in more detail based on the environment design spectrum shown in Figure 1 is needed to explore other possibilities of environment design. For example, semi-featured elements such as furniture may be presented in a virtuality-based space, while a reality-based space might be empty in some cases. Second, studies that consider additional factors that can affect user experience are required. For instance, different types of object interaction or locomotion styles may expand one's spatial experience. A user might evaluate a reality-based environment as a new space by providing unrealistic interaction types. However, there are very few studies on specific factors that influence the user experience of social VR, especially those related to environment design. Third, a team arrangement considering the difference in individual traits, experience level, or cultural characteristics might be considered. Even though the social-contextual meaning of the spatial environment can be common rather than personal (Benford et al., 2001; Gebhard et al., 2019; Patterson & Quadflieg, 2016), individual characteristics seem to affect how people evaluate an environment, which may also affect their overall experience in social VR.

6. Conclusion

The study defined the characteristics of virtuality-based and reality-based social VR environments in social VR and compared each setting. As a result of the behaviour observation and interviews in the social VR experiment conducted as a team, it found that a provided environment design may have an effect on future social interactions. Specifically, in the initial stage, active behaviour was higher in a virtuality-based environment, and individual behaviour interacting with an object was higher in a reality-based environment due to the affective responses according to the environment. Virtuality-based spaces indicate freedom to users, while reality-based spaces provide familiarity, and this contextual meaning in each environment can facilitate specific behaviours in a social VR platform.

This research contributes to exploring the possibilities and considerations of different social VR environment designs based on the perspectives of users. There are very few studies on the factors that influence the user experience of social VR so far, especially those related to environment design. This study lays the groundwork for examining the role of varied environment design in social VR. In addition, it is projected that additional aspects such as object interactions, locomotion types, and a variety of environment designs will be examined in further studies for more in-depth discussions regarding environment design in social VR.

References

1. Baker, S., Kelly, R. M., Waycott, J., Carrasco, R., Bell, R., Joukhadar, Z., Hoang, T., Ozanne, E., & Vetere, F. (2020). School's Back: Scaffolding Reminiscence in Social Virtual Reality with Older Adults. *Proceedings of the ACM on human-computer interaction, 4*(CSCW3), 1-25.
2. Benford, S., Greenhalgh, C., Rodden, T., & Pycock, J. (2001). Collaborative virtual environments. *Communications of the ACM, 44*(7), 79-85. https://doi.org/10.1145/379300.379322
3. Bowman, D. A., & Hodges, L. F. (1999). Formalizing the design, evaluation, and application of interaction techniques for immersive virtual environments. *Journal of Visual Languages & Computing, 10*(1), 37-53. https://doi.org/10.1006/jvlc.1998.0111
4. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), pp. 77-101.
5. Bukatman, S. (1992). Amidst these fields of data: Allegory, rhetoric, and the paraspace. Critique: Studies Contemp. *Fiction, 33*(3), 199-219. https://doi.org/10.1080/00111619.1992.9937884
6. Burgoon, J. K., Guerrero, L. K., & Floyd, K. (2016). *Nonverbal Communication*. New York: Routledge,.
7. Davis, A., Murphy, J. D., Owens, D., Khazanchi, D., & Zigurs, I. (2009). Avatars, people, and virtual worlds: Foundations for research in metaverses. *Journal of the Association for Information Systems, 10*(2), 90-117.
8. Díaz, J., Saldaña, C., & Avila, C. (2020). Virtual World as a Resource for Hybrid Education. *International Journal of Emerging Technologies in Learning (iJET), 15*(15), 94-109.
9. Dionisio, J. D. N., III, W. G. B., & Gilbert, R. (2013). 3D virtual worlds and the metaverse: Current status and future possibilities. *ACM Computing Surveys (CSUR), 5*(3), 1-38.
10. Fleury, S., Blanchard, P., & Richir, S. (2021). A study of the effects of a natural virtual environment on creativity during a product design activity. *Thinking Skills and Creativity, 40*, 1-9.
11. Flobak, E., Wake, J. D., Vindenes, J., Kahlon, S., Nordgreen, T., & Guribye, F. (2019) Participatory Design of VR Scenarios for Exposure Therapy. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1-12.
12. Frank, M. G. (2016). *Understanding nonverbal communication*. Virginia: Teaching Company.
13. Freeman, G., & Maloney, D. (2021). Body, avatar, and me: The presentation and perception of self in social virtual reality. *Proceedings of the ACM on human-computer interaction, 4*, 1-27.
14. García-Batista, Z. E., Guerra-Peña, K., Alsina-Jurnet, I., Cano-Vindel, A., Martínez, S. X. H., Jiménez-Payano, D., ... & Medrano, L. A. (2020). Design of virtual environments for the treatment of agoraphobia: inclusion of culturally relevant elements for the population of the Dominican Republic. *Computers in Human Behavior, 102*, 97-102.
15. Gebhard, P., Schneeberger, T., André, E., Baur, T., Damian, I., Mehlmann, G., König, C., & Langer, M. (2019). Serious games for training social skills in job interviews. *IEEE Transactions on Games, 11*(4), 340-351. https://doi.org/10.1109/TG.2018.2808525
16. Gunkel, S. N., Stokking, H. M., Prins, M. J., van der Stap, N., Haar, F. B. T., & Niamut, O. A. (2018). Virtual Reality Conferencing: Multi-user immersive VR experiences on the web. *Proceedings of the 9th ACM Multimedia Systems Conference*, 498-501.
17. Heydarian, A., Carneiro, J. P., Gerber, D., Becerik-Gerber, B., Hayes, T., & Wood, W. (2015). Immersive virtual environments versus physical built environments: A benchmarking study for building design and user-built environment explorations. *Automation in Construction, 54*, 116-126.
18. Jeon, H. J., Youn, H. C., Ko, S. M., & Kim, T. H. (2022). Blockchain and AI Meet in the Metaverse. *Advances in the Convergence of Blockchain and Artificial Intelligence*, 73-82.
19. Jonas, M., Said, S., Yu, D., Aiello, C., Furlo, N., & Zytko, D. (2019). Towards a taxonomy of social vr application design. In *Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*, 437-444.
20. Kullmann, K. (2014). Hyper-realism and loose-reality: The limitations of digital realism and alternative principles in landscape design visualization. *Journal of Landscape Architecture, 9*(3), 20-31.

21. Latoschik, M. E., Kern, F., Stauffert, J. P., Bartl, A., Botsch, M., & Lugrin, J. L. (2019). Not alone here?! scalability and user experience of embodied ambient crowds in distributed social virtual reality. *IEEE Trans. Visualization Comp. Graphics, 25*(5), 2134–2144. https://doi.org/10.1109/TVCG.2019.2899250
22. Maloney, D., Freeman, G., & Wohn, D. Y. (2020). "Talking without a voice": Understanding non-verbal communication in social virtual reality. *Proceedings of the ACM on Human-Computer Interaction, 4*(CSCW2), 1–25.
23. McVeigh-Schultz, J., Kolesnichenko, A., & Isbister, K. (2019). Shaping pro-social interaction in VR: An emerging design framework. *Proceedings of the 2019 CHI conference on human factors in computing systems*, 1–12.
24. Moustafa, F., & Steed, A. (2018). A longitudinal study of small group interaction in social virtual reality. In *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*, 1–10.
25. Mura, G. (2007). The metaplastic virtual spaces. *International conferencee on virtual systems and multimedia*, 166–178.
26. Mütterlein, J., Jelsch, S., & Hess, T. (2018). Specifics of collaboration in virtual reality: how immersion drives the intention to collaborate. *PACIS 2018 Proceedings, 318*, 1–15.
27. Ondrejka, C. (2004). Escaping the gilded cage: User created content and building the metaverse. *NYL Sch. L. Rev, 49*, 81–101.
28. Patterson, M. L., & Quadflieg, S. (2016). The physical environment and nonverbal communication. In D. Matsumoto, H. C. Hwang, & M. G. Frank (Eds.), *APA handbook of nonverbal communication*. American Psychological Association.
29. Strate, L. (1999). The varieties of cyberspace: Problems in definition and delimitation. *Western Journal of Communication (Communication Reports), 63*(3), 382–412. https://doi.org/10.1080/10570319909374648
30. Tanenbaum, T. J., Hartoonian, N., & Bryan, J. (2020). 'How do I make this thing smile?' An inventory of expressive nonverbal communication in commercial social virtual reality platforms. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–13.
31. Yassien, A., ElAgroudy, P., Makled, E., & Abdennadher, S. (2020). A design space for social presence in VR. *Proceedings of the 11th Nordic Conference on Human-Computer Interaction*, 1–12.