"I Am a Mirror Dweller": Probing the Unique Strategies Users Take to Communicate in the Context of Mirrors in Social Virtual Reality

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Figure 1: VRChat user dancing in front of a mirror (a) ; Users gathering in front of a mirror in social VR (b) ; The avatar's movements in social VR are consistent with the user's offline physical movements in real time (c)

ABSTRACT

Increasingly popular social virtual reality (VR) platforms like VR-Chat created new ways for people to interact with each other, generating dedicated user communities with unique idioms of socializing in an alternative world. In VRChat, users frequently gather in front of mirrors en masse during online interactions. Understanding how user communities deal with the mirror's unique interactions can generate insights for supporting communication in social VR. In this study, we investigated the mirror's synergistic effect with avatars on behaviors and dedicated user conversational performance. Qualitative findings indicate that avatar-mediated communication through mirrors provides functions like ensuring synchronization of incarnations, increasing immersion, and enhancing idealized embodiment to express bolder behaviors anonymously. Quantitative studies show that while mirrors improve self-perception, it has a potentially adverse effect on conversational performance, similar to the role of self-viewing in video conferencing. Studying how users interact with mirrors in an immersive environment allows us to explore how digital environments affect spatialized interactions when transported from physical to digital domains.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in collaborative and social computing**.

KEYWORDS

Social VR, body illusion, mirror, avatar-mediated communication

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1 INTRODUCTION

Rapidly growing commercial social VR applications have coincided with a boom in research on social VR in HCI, such as empirical studies that investigate types of social interactions that users engage in in social VR [20, 61, 62, 70, 98], identity construction [35, 36, 38], and social VR design choices [50, 69, 86]. Through the use of head-mounted displays (HMDs), social VR allows multiple users to simultaneously interact with each other in immersive 3D environments that afford more embodied experiences compared to traditional 2D online spaces [61, 64, 69, 70, 88].

Despite the diversity of modes of communication available in social VR, synchronous voice chat is still the most predominant means of communication [37]. In dialogue-heavy social VR applications such as VRChat, having smooth conversations is a highly desirable social experience to users [37], making it critical to explore what and how different factors impact user conversations in social VR. In particular, there has been an increasingly heated discussion on the impact of mirrors on user social experiences in VRChat game communities such as Steam [4], suggesting that plenty of social interactions take place in front of mirrors, such as gathering to chat in front of mirrors. Mirrors in VRChat worlds are so prevalent that one can hardly find a digital public world without any mirrors [6]. The growing discussion in the game community motivated our study that ponders questions about the role of mirrors in user socialization, which has been seldom explored [66]. To our knowledge, there has been only one empirical study that observed the social phenomenon where users gather in front of VRChat mirrors for long durations with a variety of avatars [66]. Yet this study did not investigated how users perceive the role of mirrors in social VR and how mirrors impact socialization and conversation in VR.

In turn, a large body of work has explored the psychological effect of mirrors in real life situations, such as the use of mirror-like features like self-views in video conferencing [21, 31, 40–42, 56, 59]. These studies suggest a role for mirrors in influencing emotional behaviors [21, 31, 56, 59], by way of self-awareness construction [40, 41]. While some studies suggest a neutral or even positive impact of mirrors on emotional well-being (e.g., maintaining or mitigating social anxiety during conversation [21]), others maintain that mirror-like objects like the self-view mode distracts users from indulging in conversations [10, 30]. However, none of the existing literature has explored mirrors in the field of social VR, where communication is mediated by avatars [38].

When looking into mirrors in social VR, users see their own avatars, rather than their physical body in real life. Previous studies on avatars suggest that they facilitate communication in two ways. First, the Proteus effect associated with an avatar suggests that users are affected by their attachment to virtual identities in social VR, where there are fewer limitations in their self-expression. Thus, their interactions are decisively different between the offline world and online digital spaces [35, 94, 96]. Second, avatars provide users with anonymity that encourages more daring communication without worrying about disclosing privacy [16, 64]. However, the effect of avatars on users when mirrors are turned on in social VR has yet to be explored.

To understand the role of mirrors in avatar-mediated social VR we conducted a mixed-method study consisting of a set of qualitative interviews involving dedicated users exploring RQ1, and a controlled experiment and follow-up interviews investigating RQ2:

RQ1: *How do users behave and perceive themselves in the context of mirrors in social VR?*

RQ2: *How do mirrors influence user conversational performance in social VR?*

Our qualitative findings highlight: (1) the unique ways participants engage with mirrors in VRChat, e.g., showcasing and sharing the presentation of avatars with friends in front of mirrors; (2) users' positive perception toward the role of mirrors in VRChat, e.g., increased satisfaction, confidence, etc. In our quantitative experiment, we first measured the difference of conversational performance under two conditions (mirrors on and off). Then, we interviewed the participants about their thought processes and perception of mirrors during the experiment. The results reveal a gap between user perception of mirrors and their actual conversational performance.

Our contributions include: (1) qualitative findings regarding VRChat users' perception and use of mirrors in their social VR experiences; (2) evaluation of the impact of mirrors on user conversational performance in VR; (3) design considerations for facilitating user communication and social interaction in VR.

2 BACKGROUND AND RELATED WORK

Our study explores the significance of mirrors in social VR with regard to meaningful social activities, and how mirrors impact user perception and socialization. While a large body of work has studied social activities (e.g., dancing, activities for improving social skills such as chatting, etc.) and communication modes in social VR (e.g., non-verbal communication and avatar-mediated communication modes), the predominant means of communication in social VR is synchronous voice chat. In this section, we review literature on the prevalence and significance of mirrors in social VR, studies conducted in offline settings from psychology that potentially explains mirror-related phenomena, and the unique affordances of avatars that may interact with the effect of mirrors in social VR.

2.1 Social VR and Mirrors

Social VR refers to a set of applications where multiple users interact with each another in 3D virtual environments [34] using immersive technologies [99]. Over the past decade, popular social VR applications like VRChat, Altspace, RecRoom, and Facebook Spaces have opened up emerging research areas, such as empirical studies that investigate social interactions [20, 61, 62, 70, 98], identity construction [35, 36, 38], and design choices in social VR [50, 69, 86].

In order to enhance virtual social communication [91], social VR provides diverse communication modes that enable users to practice social skills with unique affordances [61, 70, 72, 81]. For example, prior work suggests that real-time non-verbal behaviors enabled by VR HMDs and full body trackers allow users to have more natural and embodied means of communications [88] that can improve people's social skills [64]. Despite this, the most predominant means of communication in social VR is still talking to each other through synchronous voice chat [37], making it crucial to understand what factors impact user conversations in social VR.

One prominent influence on social VR interactions that came to our notice is mirrors, due to heated discussions on uses of VRChat mirrors in game communities [2–4, 7, 92]. Many social interactions take place in front of mirrors, such as starring at and touching each other's avatars. Virtual mirrors have such an integral place in VRChat that one can hardly find a public world without a mirror there [6, 8]. In VRChat, mirrors could be divided into 4 types: *global*, *local*, *high quality*, and *low quality*. While toggling *global* mirrors would synchronize the toggling status (i.e., on or off) to all users in the same virtual world, the toggling status of *local* mirrors is only visible to the user who toggles the mirror. While *High-quality* mirrors can reflect all the objects in the environment, *low-quality* mirrors reflect the avatar only [12]. Researchers have also investigated mirrors in VRChat. For example, an observational study points out the phenomenon that VRChat users like to stay and interact in front of mirrors with a variety of avatars [66]. However, to our knowledge, there has not been work that further investigates what types of interactions users have in front of mirrors, how users perceive the roles of mirrors in social VR, and how mirrors impact their interactions, such as conversations.

2.2 The Effects of Mirrors and Avatars

2.2.1 Psychological Effect of Mirrors in Real Life and in Video Conferencing. Use of reflective objects like mirrors and self-viewing devices is correlated with self-awareness and self-perception. Psychologists developed the mirror test as a readout for the development of self-awareness in animals [41]. Research indicate that even a quick glance in the mirror reaffirms our sense of self [93]. Lacan's "mirror stage" theory shows that by reflecting on themselves from mirrors, children can recognize for the first time that they have self identities [40]. Early laboratory studies also manipulated self-awareness by the placement of mirrors [27]. There is also strong evidence that mirrors can provide a means of increasing the occurrence of self-relevant thoughts [26, 42], which is correlated with a higher level of self-perception. Thus as a tool to influence self-awareness, the mirror affects self-perception and emotional behaviors [21, 31, 56, 59].

The influence of mirror-like objects in psychological and emotional functioning could be neutral or positive. Research shows the benefits of mirrors for perception of well-being and physical experience of our bodies[93]. Studies in offline world found that socially anxious people in a face-to-face conversation with large mirrors placed around them did not have higher levels of fear, blushing, or negative thinking than those conversing without mirrors [21]. Similarly, the feedback of self-view in video conferencing, which are most similar to the function of a mirror, also plays a protective role by reducing the effects of social anxiety [53]. Such effects of mirrors or mirror-like devices can be explained with the Clark and Wells model [59], which proposes that feedback such as objective information of how people perform in a social situation may correct untrue negative information in their mental image [53]. Such feedback therapy applies retrospective viewing of videos from social situations to correct negative self-perceptions [53]. With untrue negative perceptions of themselves corrected for, people grow to have more positive self-perception, which can lead to positive conversational performance [74].

Despite the neutral or even positive impact that mirror and self-view may bring, some studies showed that reflective tools like mirrors and self-view in video conferencing can boost self-perception while making performance worse [31, 56]. Past research had shown laboratory subjects their mirror images for a brief period of time, finding that mirrors increased self-evaluation and reduced ability to discriminate [33, 90]. In video conferencing, looking at the self-view while speaking produces equivocal effects [10]. Studies on self-view point out that people often over-focus on their appearance on the screen during an online meeting, which led to distractions [10, 30]. Such phenomenon can be explained from the perspective of seeing self-view engagement as a process of more detailed observation of online communication and occupied mental processes [10, 26]. Specifically, the over-focus on one's appearance would deplete their mental resources and undermine online meeting outcomes [10]. According to the theory of object self awareness, self-focused stimuli lead to self-evaluation, whereby one uses the true self and the ideal self as benchmarks [33]. This comparison of the "true self with the ideal self" may have negative self-regulatory consequences [10, 26].

Though studies of self-assessment tools like mirrors in the offline world and self-view in video conferencing have been well-established, none of the prior studies has investigated how mirrors as self-assessment tools [21, 53] influence people's behaviors and perception in social VR.

2.2.2 The Effect of Avatars on Perception and Behavior in Virtual Worlds. Avatars play a central role in the communicative and self-presentation dynamics in virtual worlds [38]. It is "the nexus of virtual assets that the player collects and produces while exploring online game worlds" [65] and serves as an interface for interaction between humans [39] that bridges physical and digital forms [38]. In social VR, avatar communication is realized by a body tracking system that replicates the user's posture and motion [38].

As a form of self-presentation, avatars play an essential role in establishing the illusion of body ownership [47] and influence over the embodiment experience [44] in social VR. As stated by Goffman's metaphor of a performance, self-identity is constructed in a collective and interactive process within different social settings [43]. When looking at the mirror, users obtain feedback of the appearance and movement of the self-avatar, simulating face-to-face interaction [92], and strengthening the connection between their physical body and their personalized role in the virtual world [32, 79]. By giving the avatar personality, unique behaviors, intentions, and styles, users begin to attach themselves to the avatar as a second self [38], and perceive ownership of the avatar's body as a form of embodiment illusion [44].

The various avatars that exist in social VR can significantly alter a person's body schema and social role [19, 87]. Using embodied avatars can lead to increases in the subjective sense of presence inside VR [85], increasing the illusion of place, the plausibility of the experience, [83, 84] and the level of immersion [82, 84]. A body of work indicates that the use of embodied avatars lead to behavioral and attitudinal changes [51, 54, 75, 76, 95, 96]. This is related to the Proteus effect [94, 96], which describes the phenomenon where people conform to their avatar and the mental makeup of their avatar, impacting their behaviors, attitudes, perception, and cognition [35]. In social VR, the Proteus effect can be experienced

in a more embodied manner due to the direct connection between the physical self and the avatar through body tracking system [35]. Such involvement of both the physical body and the avatar often leads to a more realistic perception of self-presentation [35].

Avatars facilitate communication in social VR [91], including enabling users to express themselves while maintaining anonymity and privacy [16, 64]. For example, avatars empowered introverted older adults to participate in social activities [15, 16], and protected marginalized users from unwanted behaviors while still being able to communicate in a socially satisfying environment [64]. The use of avatars allows co-presence in virtual spaces, which diminishes the physical and psychological distance of social interaction in social VR compared to communication in other types of platforms [58, 97]. Applying an embodied avatar for self-presentation, users have a greater sense of social presence, stronger bonding with partners, and higher communication quality while being more considerate and less aggressive [85]. The appearance of the avatar appearance also affects communication experience. These visualized appearances often convey emotional information in a way that is not possible in the real world [17], while realistic-looking avatars makes communication and collaboration with the other users more comfortable during and between tasks [49].

In summary, gathering around and chatting in front of mirrors with an avatar for self-presentation is a common phenomenon in VRChat, and is unique to the digital world. However, despite the well-established studies on the psychological effects of mirror-like objects in the physical world, as well as the effect of avatars on behaviors and perceptions in virtual reality, the synergistic effects of mirrors and avatars on communication and perception in social VR remains unexplored.

3 METHODS

Due to the predominance of synchronous voice chat in social VR [37], we decided to include a remote quantitative experiment with conversational tasks to investigate the effect mirrors have on conversational performance and observe the influence of mirrors on interpersonal communication, which is too complex to be measured directly. Due to the exploratory nature of our research questions, we conducted a semi-structured and go-along interview after the quantitative experiment to investigate how users perceive and understand the role of mirrors and how mirrors influence conversational performance and behavior in social VR. We chose experimental designs and interviews because they offer greater internal validity for learning what the effects of a social program are [80] while being able to obtain detailed information from a small number of participants [11]. In order to obtain interpersonal communication behavioral insights in the participants' natural state [91], the experiment was designed as a remote VR study [63], and strictly followed the institutional ethical regulations for social VR research.

3.1 Participants

Participants (N=22, 7 females, 14 males, 1 trans female) (see Table 1) were VRChat players recruited through social media and posts on VRChat player group chats, with 22 participants conducting the quantitative experiment and 19 in the qualitative section. All participants were native Chinese speakers aged from 18 to 28 (average age: 21.9) with diverse VRChat experience ranging from below 3 months to above 12 months. All participants own their own VR headsets and use the headset for most of their communication in social VR. Before the experiment, all participants signed an online consent form and were given a prompt for their particular condition. Participants were compensated with 50 RMB after completing the experiment. The study was approved by institutional IRB.

In regards to the participant sample size of our two condition within group study, in practice a priori power analyses may not reflect experimental conditions because it hinges on knowing the variance in a sample before the data is collected, which is uncommon in exploratory HCI studies. Therefore, using the same number of participants as in previous validated related research would be more appropriate [60]. A published work using an experiment similar to our own [74] uses a 2×2 within subjects factorial design to study speaking performance, and reported statistically significant results with 18 participants. Moreover, a prior two condition within subjects study involving head-down displays used 24 subjects [24]. On the other hand, it is generally accepted that in ideal power analysis ($1 - \beta$ err prob), the effect size needed to indicate large measurable differences should reach 0.8 [29]. The G-power software [5] was used to calculate the number of subjects of a paired-t test (Power=0.8, Effect size dz=0.8, α err prob=0.05, Two Tail) and the results suggest that the total sample size should be greater than 15 subjects. Thus a sample size of 22 participants for the quantitative experiment should be able to detect such measurable effects.

3.2 Design

3.2.1 Topics for Conversational Task. Social conversations are more random and harder to observe when everyone talks about different topics. Instead, we chose more casual topics than formal speech while still avoiding influence from personal experience. The two topics are "Do you think nowadays people are healthier than people one hundred years ago?" and "Do you think a person should have just one job or many jobs throughout their life?". The researchers provided the topics by asking the questions in a casual way to make the speaking more conversational and encourage participants to speak freely. We counterbalanced the order of the conditions and questions for each participant, and ensured researchers asked the two questions the same number of times under each condition.

3.2.2 Experimental Environment. Instead of inviting the participants to our lab in person, we conducted the experiment remotely in VRChat, inviting participants to join the study in their familiar physical environment to capture natural social behavior [91]. In the virtual world, we built a square VRChat space with walls replaced by four so-called local low-quality mirrors and switches on the floor. The local and low-quality mirror refers to the toggling status of the mirror in our experiment space, which is only visible to the user who toggles the mirror and can reflect the user's avatar with all spatial elements non-reflected to avoid possible visual disturbance. Since we found in the pilot study that some people prefer to look to the right/left side due to personal habits, we used the four mirrors to allow the spatial influence to work on all participants. We used the entrance way to manage accepting the invitation from researchers, after which participants are automatically sent to the experimental space. This models participant daily experience, as the portal is the
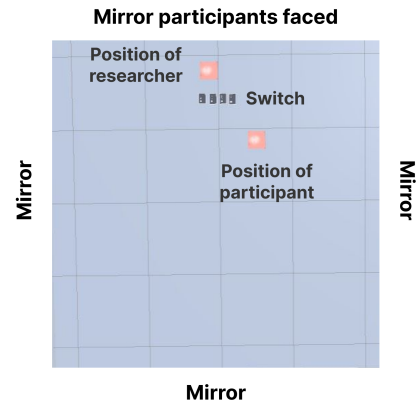
Table 1: Demographic Information of Participants

ID	Gender	Age	Experience in VRChat(months)	Time spent on VRChat(hr/w)	Education level
P1	Female	22	>12	>6	Bachelor's degree
P2	Female	22	<3	>6	Bachelor's degree
P3	Female	28	<3	<1	Master's degree
P4	Female	18	6~12	4~6	n/a
P5	Female	23	>12	1~3	Master's degree
P6	Female	23	3~6	>6	Bachelor's degree
P7	Female	24	3~6	>6	Bachelor's degree
P8	Trans Female	18	3~6	>6	Less than high school
P9	Male	25	>12	>6	Less than high school
P10	Male	22	>12	4~6	Bachelor's degree
P11	Male	27	3~6	1~3	Bachelor's degree
P12	Male	21	3~6	>6	Bachelor's degree
P13	Male	25	3~6	>6	Bachelor's degree
P14	Male	25	3~6	>6	Bachelor's degree
P15	Male	18	6~12	4~6	Less than high school
P16	Male	24	3~6	>6	Less than high school
P17	Male	18	6~12	>6	High school graduate
P18	Male	18	>12	>6	Bachelor's degree
P19	Male	18	<3	>6	Less than high school
P20	Male	20	>12	>6	Bachelor's degree
P21	Male	21	3~6	>6	Bachelor's degree
P22	Male	21	>12	>6	High school graduate

Note: n/a - participants prefer not to answer

only way to get into a new world in VRChat. Participants were asked to stand in a pre-defined position close to one of the mirrors (see Figure 2) to ensure they could see themselves clearly, while researchers stood in front of the participant on the left. To ensure the consistency of experiment procedures and measurements, all experiments occurred in the same position, and researchers video recorded from a fixed angle on PC with permission.

3.2.3 Avatar. We chose a set of specific avatars for our participants in this study as diverse avatars are not appropriate in the controlled format, and the avatar's appearance could affect self-perception in conversations [94]. For example, the height of the avatar could influence confidence in negotiation [13]. We kept the horizon of the avatar of researchers and participants at the same level to avoid bias. When choosing the avatar, we felt the need to provide embodied avatars to increase both the place illusion and the plausibility of the experience. In social VR, players prefer to construct consistent self-presentation similar to their physical self and humanoid avatars rather than those with no gender (e.g., robots) [35, 45] for higher embodiment illusion. Since our participants are all binary people (with one transgender but identifying herself as female), we prepared humanoid avatars with the same style but different genders instead of animal avatars, and let the participants choose the avatar that aligns with their gender identity.

3.2.4 Scoring the Public Speaking Competence Rubric (PSCR). Rubric (PSCR) is a 10-item measure that employs a 5-point Likert scale [78]

Figure 2: Overhead view of the pre-designed experimental space

allowing observers to rate public speaking performance with adequate internal consistency [28]. During the remote experiment in VRChat, we encouraged the participants to use their most familiar equipment. Therefore some participants may use full-body tracking kits while others may only track the upper body. We focused on the upper body when scoring non-verbal behaviors to ensure

(a)

(b)

(c)

(d)

Figure 3: Avatar for participant who identifies herself as female (screenshot from researcher's vision)(a); Avatar for participant who identifies himself as male (screenshot from researcher's vision)(b); Mirror on(from participant's vision)(c); Mirror off(from participant's vision)(d)

consistent scoring. As we only calculate the difference between the scores of each individual's performance under the two contexts, the only variable we need to be blinded for when scoring is the mirror's presence. We recorded the experiment from the researcher's perspective on PC to maintain a stable and fixed angle for scoring. During the process of video recording, we kept the mirror of the researchers' side open during the whole experiment (see Figure 3(a) and Figure 3(b)) to ensure that scorers won't be affected by the condition of mirrors when watching the recording.

The video recording of each round of experiment was anonymized and order-randomized before being sent to the scorers. The two scorers performed initial scoring according to Rubric's criteria, giving examples of what it is like to get a score of 1, 3, and 5 respectively, then discussed the differences, and unified the criteria of scoring. Each speaking performance was rated by two scorers and a two-way random *Intraclass Correlation Coefficients* (ICCs) [77] for consistency of the average was calculated for each speaking performance. The ICCs for each item of the rubric range from 0.645 to 0.836 with an average of 0.719. For the public speaking rating process in the present sample, the level of reliability of the rubric was deemed acceptable. We obtained the average score of the two scorers as the final score for further analysis. Since the scale was used for those wearing VR headsets who cannot take notes, we adjusted the definition of rating score 1 of the item to "Appears comfortable with audience." When rating this item, we focused on the communication through eye contact, interaction with aids, and

physical gestures instead of the level of participant's dependence on notes. In the measurement of eye contact, scorers could feel the changes of participant's sight angle from the video recording, such as blinking, rotating eyes, looking directing to the researchers, or turning their perspective to the mirror. The interactivity of eye contact the scorers feel from the video recording is evaluated as the dimension of eye contact in the rubrics, analogous to a rating of the appropriateness of visual interaction in daily conversation.

3.3 Procedure

3.3.1 Qualitative Data Analysis. The video recordings and interview transcriptions were analyzed using qualitative analysis methods to probe participant thought processes during the experiment. Following CSCW and HCI qualitative coding guidelines [68], we identified and summarized recurring themes, and found connections between each theme for organizing them into clusters of more complex themes.

Our coding and analysis procedures were: 1) two authors read through the collected data to acquire participants' thoughts and self-perception during the quantitative experiment, a general picture of the social meaning of mirrors in social VR and user experiences related to spatial elements that influenced social experiences in VR; 2) two authors identified thematic topics and common features in the collected data; 3) one author took a full review of the thematic topic to develop sub-themes; 4) one author refined all the themes
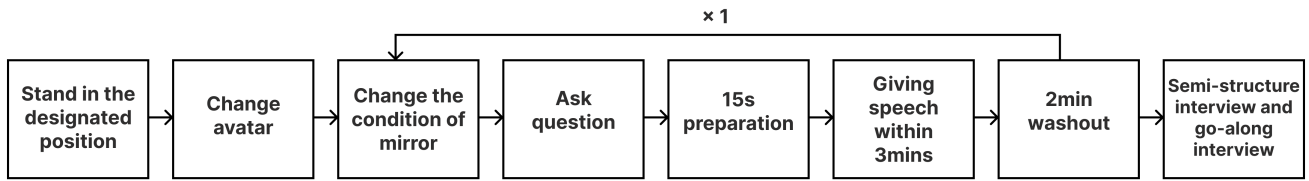
Figure 4: Diagram of the experimental flow

and features to develop a description of the unique properties of mirrors in social VR.

3.3.2 Positionality Statement. In qualitative research, it is essential for researchers to acknowledge and disclose their selves to better understand their influence on the research process, interpretation, and understanding of the data [46, 67]. Such disclosure would also influence the extent of belief in the truthfulness and validity of the readers [48, 73]. Therefore, it is necessary to share the context of researchers' positionality in relation to the participants. The thematic analysis is conducted by authors with approximately three months of experience in VRChat, which enables them to have a general picture of the culture [48, 71] of the VRChat community while also being able to sufficiently detach themselves from the culture anytime to be able to study it without bias [57]. Besides, the authors are about the same age with the average age of participants and share the similar cultural and linguistic background. Therefore, the authors are able to have a better understanding of what participants want to express, including colloquial language and non-verbal cues, and reduce the potential disorientation due to 'culture shock'.

3.3.3 Experiment Procedure. Prior to the intervention, we provided an informed consent document to all participants based on their communication preferences, via email, WeChat, or QQ message. We collected participants' self-reported pronouns to describe their identity experiences and practices in social VR. We then arranged time to meet the participants individually and remotely via VRChat. The participants used their own accounts to log in. After receiving the invitation from researchers, they were automatically sent to the experimental space, which models the way they usually enter any other VRChat space.

Upon the participant entering the experimental space, there is time for brief greetings so that the participant and researcher can familiarise themselves with each other. Researcher then confirmed with the participants to make sure they were fully immersed in their own most-used VR headset. Each participant was asked to stand in the marked place and chose an avatar that aligned with their gender identity. This was followed by an introduction and instructions on the intervention. Participant was then given time to change the condition of mirrors under researcher's instruction and ask questions about the experiment before the video recording started. The researcher provided the question by asking in a casual tone. Participants were given 15 seconds at most to think before speaking, and then stated their points with supporting reasons within 3 minutes after preparation. They were encouraged

to express as casually as possible and researchers responded in a relatively muted way, such as "hummm" to agree, to maintain the communication without affecting the content of the conversation. At the end of each round, participants were given 2 minutes of wash-out to minimize the influence of the last round. The quantitative section was followed by the semi-structured and go-along interview. Participants were asked to take the researcher to their preferred VRChat space and places where mirrors relate to their experience for the go-along interview to better understand their experience with VRChat mirrors in a natural environment. The interview began with questions about participant's self-perception in conversational tasks. The main questions of the interviews are related to user experience with mirrors in social VR platforms, social interactions, and relationship building in social VR. Example interview questions include: "How will you feel in front of mirrors in VRChat?", "What do you usually do in front of the mirror?", "Why do you think people like to gather in front of mirrors in VRChat?", "Do you think body language could better your self-expression in social VR?", "Which VR space do you tend to make friends in?", and so forth. We video-recorded the entire process of the interview under participant's permission for data analysis.

4 RESULTS

4.1 Mirror-Related Interactions and Perceptions

Using quotes from users' accounts about their past experience related to mirrors in social VR in the go-along and semi-structured interviews, we present our findings here as two parts. First, we identify the main themes emerging in participants' experiences and practices with regard to how they interact with mirrors and what they do in front of mirrors in social VR. Second, we highlight how mirrors affect users' self-perception in social VR.

4.1.1 Clustering Effect in Front of Mirrors. Mirrors are found in almost every social VR map. In VRChat, a large number of players gather in front of mirrors chatting with each other. As P6 mentioned, *"There was a big mirror inside a popular public space called Chinese bar where people gathered, chatting and dancing. Almost all the people in the Chinese bar are in the big mirror area and it's rare to see players elsewhere on the big map."* P20 also shared a similar experience, *"In the very hot map, which is called Japanese shrines, people like to gather in front of the mirror."*

As for why people like to gather around the mirror, some players say they like to chat with their friends next to mirrors as they provide a sense of support. As P8 pointed out, *"People generally*

like to chat in front of the mirror in VRChat, sitting in a circle, which adds a sense of mutual support to the atmosphere." According to P9, *"Gathering to chat usually has mirrors, unless it's a more cordial experience to chat like at a campfire."* It appears that chatting in front of mirrors makes people closer and more likely to feel emotionally supported by each other. The feeling of being supported may be related to the instant feedback of others which can be seen through mirrors even though there are a lot of people that may block the view. Just as P6 expressed, *"You can see the reaction of your friends through a mirror when chatting with them. For example, when you tell your friends a funny thing, they will be happier and will do some actions like smile to respond you. and it is really interesting to catch the response through mirrors!".*

In addition to emotional support, mirrors also compensate for the lack of ability to sense in remote VR chat to some extent, adding more background information for the conversation. Two participants mentioned that when there were mirrors, they can see what's behind them. P21 highlighted, *"Inside the VR, the mirror can present a wider perspective. This way I can also know what's happening behind me and whether anyone is approaching me because I don't hear very rich sounds, such as footsteps in social VR, as I do in the physical world."* Thus, the wider view provided by the mirror can compensate for the lack of sound information in the VRChat environment.

In addition to the active players, there are also players who simply log on and place themselves in front of the mirror but do not interact or respond to anyone. Six participants mentioned that they liked hanging out in front of mirrors without doing anything. P12 pointed out, *"Sometimes I log on to VRChat, just move near the mirror, and then do something else on the computer. If someone comes to talk to me, I may hear voices and switch to VRChat and start the conversation with the new player or just my old friends."* In this case, it seems that VRChat serves the same function as other social platforms. When you are logged on, you can do other things while expecting social interactions to occur. Two other participants also said that they do not initiate a conversation, but prefer to stay in front of the mirror and wait for someone to come to them to start the conversation. P12 continued to explain why he chooses the mirror as waiting areas for interaction, *"Staying in front of the mirror can validate your existence even though you may be away."* It seems that being in front of a mirror is more likely to get someone's attention and start communication compared with other places, forming an unspoken social rule in VRChat.

Going to the mirror appears to be a habituated existence to VRChat players. Four participants said the first thing to do when they enter a new map is to open the mirror. For new VRChat players, they may also take the initiative to adapt to this habit. As described by P7, *" Because there is a group of people communicating in front of the mirror, it doesn't look awkward to join, and it is also easier to find common topics because of the large number of people."* It seems that joining the conversation at the gathering place can avoid awkwardness for socialization. Compared with the local mirror, the public mirror is more important and irreplaceable. P7 explained, *"Even if there are mirrors in the menu that can be dropped out of local personal visibility, a public mirror where you can see everyone not only yourself in map is almost an indispensable part of the VRChat experience. I love the feeling of sitting around in front of the mirror chatting with my friends."*

There are also other reasons why mirrors are irreplaceable in social VR. When switched on in VRChat, the reflected content and quality selection of the mirror make it an interactive item. Given the relative lack of interactive content in VRChat, P12 said he usually likes to chat with his friends in front of the big mirror because the big centered mirror is almost the only interactive item in the landmark map. As an interactive item, the mirror is also very commonly seen in VRChat. As a very early VRChat player, P13 makes an explanation for why mirrors are so common, *"Because the entrance to the original map had mirrors, and this early setting allowed players to get used to the presence of mirrors. So when they design a VRChat map, they enjoy putting mirrors in."* In all, the habitual and irreplaceable nature of mirror makes the clustering effect in front of mirrors appears to be a special phenomenon that forms part of VRChat culture.

4.1.2 Avatar Provides Social Masks and Encourages Bold Behaviors in Front of Mirrors. Appearing as an anonymous embodiment in social VR will allow for more confident expression and social interaction. Four participants expressed that in VRChat, everyone is in the avatar image and will not feel inferior due to physical defects of one's self in reality. Hence it's easier to chat with people. As P8 pointed out, *"The avatar in the mirror is equivalent to putting a mask on yourself, so you will be more confident to express yourself when seeing the avatar through the mirror."*

In VRChat, players present themselves through an avatar-mediated mask, making it more likely to perform unique behaviors in front of mirrors that differ from in real life. For example, P21 noted, *"I like to touch others in front of the mirror and to be touched by others with a relaxing sensation, which feels like a current flowing through body."* This is a phenomenon called Phantom Sense in VRChat. It refers to the brain tricking players into feeling touch sensations on their virtual bodies in VR, leading to a comfortable, relaxed state. The immersive property of VR allows for synchronization of real-world behaviors to nonverbal cues. This creates social VR activities like full-body tracking players as they dance in front of the mirror. P6 shared her experience dancing while facing mirrors in VRChat, allowing her to see the audiences' names clearly and greet them. Other participants mentioned they enjoy lying on the bed looking at the mirror on the ceiling while talking with others.

Although avatar-mediated communication in front of mirrors gives social VR players a sense of immersion and the confidence to speak, it also leads to potential ethical issues. According to P7, *"I've seen some erotic role play behaviors take place in some public maps, like an erotic dance performance in front of a mirror. Even private spaces in some maps are designed for erotic behaviors."* Two participants summarized, *"In VRChat, everyone appears in the image of an avatar, so it does not seem strange to do things that are not in line with the social norm like some harassment."* According to this, behaviors that are constrained in the real world may occur in VRChat. This could lead to problems in the VRChat community due to the lack of regulations for certain behaviors during immersion.

P5 also gives an opinion on the diverse activities in VRChat, *"In VRChat, many experiences are made easier and can be achieved in a more cost effective way than in real life. All I need is a headset, and through the immersion it provides I can access many things that I can't afford and can not do in reality."* In another word, he believes
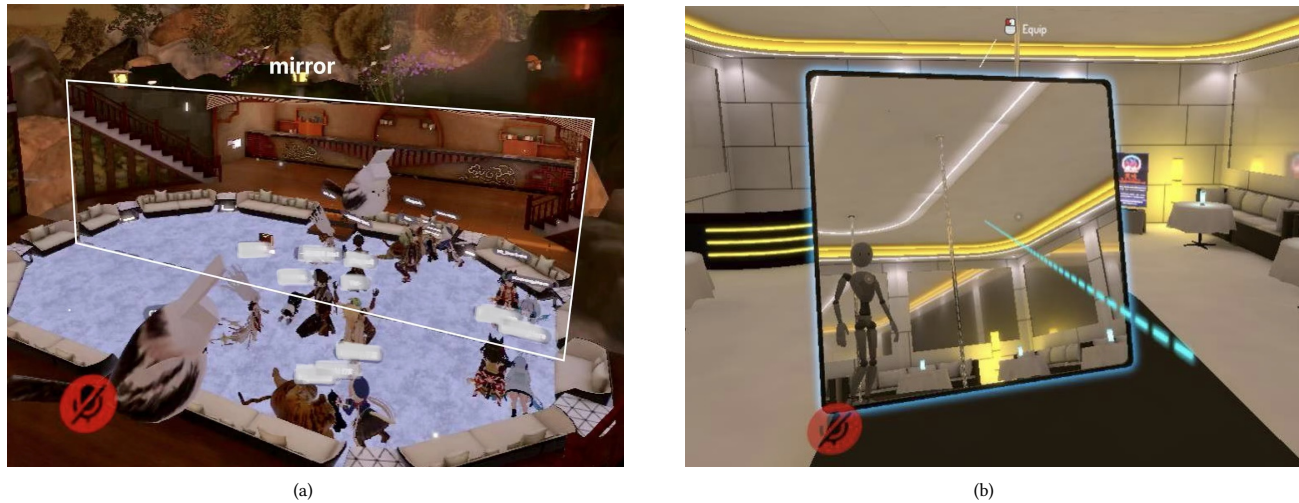
Figure 5: People gather in front of mirror in social VR(a); The personal mirror that can only reflect the owner of the mirror(b)

that in the virtual world, many things happen more easily than in the real world because of the low cost and lack of restrictions.

4.1.3 Using Mirrors to Check Grooming and Movements of Avatars. In the VRChat world, player avatars are their self-presentation in the virtual world, with grips, helmets, and full-body tracking devices that can replicate user movements in real life. However, because these devices sometimes can not keep completely synchronized with the movements in the real world, users have to check and calibrate the movements through the mirror. As three participants expressed, *"VR devices do not fully track the body and lack control over limbs, posture and expression, so mirrors come in to provide feedback."* As there are difficulties for the current VR headsets to recognize and map realistic expressions precisely, facial expression is also widely mentioned as the part that needs to be confirmed as appropriate in front of a mirror. P7 implied that opening the mirror could confirm her status and reveal whether her facial expressions were appropriate. In addition to ensuring that expressions and body movements are consistent with one's expectations, the mirror is also helpful for controlling small movements that are habitual but not socially conducive. Six participants expressed that they believed opening the mirror could control involuntary actions and make the image presented in VRChat more appropriate.

The mirror not only ensures accurate synchronization of realistic actions, but also plays a role in the accuracy of the presentation of avatar appearances. Because avatars are usually designed to have human body shape, players need mirrors to make sure avatars appear in proper shape. Just as P5 highlighted, *"Sometimes the skirt will flutter up and let the model go naked. I want to use the mirror to avoid this kind of indecent behavior to avoid embarrassment in the public world."* Also, in VRChat, you can freely change your avatar and upload your avatar with your own design, just like changing clothes in real life. Seven participants highlighted that they like to change their avatar in front of the mirror, check the avatar's look and function, special effects and props, etc. As a player who makes her own avatar models, P7 mentioned that when she tried

the avatar model function for testing, she would use a mirror to confirm that the changes of avatar model are correct.

4.1.4 Mirrors Enhance Self-perception by Presenting an Ideal Embodiment. Facing the mirror, users can embody the avatars from a first-person perspective. When doing so, participants have the feeling that their own body has been substituted by the self-avatar, and that the new body is the source of the sensations. In VRChat, people appear to be obsessed with looking into the mirror just as in reality. P8 expressed his feelings, *"When I don't see the mirror, I feel like I am facing the reality of myself, and feel anxious and nervous and overwhelmed."* P12 likened this experience to the self-view in Zoom, *"I am very used to talking in front of the mirror, and just like when using Zoom meetings, I used to turn my own video to the maximum to get feedback."* Thus, the lack of self-feedback brought about by mirrors can cause anxiety. Moreover, self-feedback appears to contributes to self-consciousness in social VR. P22, a participant with long-term map design experience, said, *"Mirrors play the role of telling players in the virtual world who they are, helping them to complete the process of self-awareness in the virtual world."*

As in reality, self-awareness can be enhanced by looking in the mirror. In VRChat, however, players can appear as customizable avatars that reflect their ideal design. The high autonomy of content production in VRchat gives avatars many features, allowing users customize. It means that avatars are often the embodiment of one's ideals in the virtual world of social VR. Many of the players interviewed said they enjoyed admiring their avatars in the mirror. In VRChat, appearing in front of a mirror with an ideal image is a way to get validated feedback, and is conducive to better self-perception. For example, P9 highlighted that appreciating the avatar's appearance in front of the mirror would be a key reason players gather in front of the mirror. P1 shared her own experience, *"In real life, unless I was well dressed up, I may not have anxiety facing mirrors. It is not the same in VRChat where we dress in our favorite avatar and I always like to admire myself in the mirror."*

(a)

(b)

Figure 6: Staying in front of a mirror doing nothing in a scenic space(a) ; Phantom sense phenomena: physical interaction in front of a mirror (b)

(a)

(b)

Figure 7: Avatar is the ideal embodiment of the player (a); Players taking photos in front of a mirror in VRChat (b)

Taking pictures in front of mirrors, sharing with friends, and up-loading to the community were also mentioned by VRChat players. These behaviors showed participant satisfaction with the image they presented. P8 said that she liked to take pictures in front of the mirror with friends and also share with them, because she was satisfied with her image and appearance of the avatar in VRChat. P4 also shared that she likes to pose in front of the mirror and take photos because she thinks she looks cute, which brings her satisfaction. During the many times the player looks in the mirror, the player constantly confirms their self-presentation in VRChat, which brings self-satisfaction and joy.

4.2 Conversational Task

By using mirrors as a variable in a conversational task, we show in this part of the results how mirrors influence users' conversational behavior and perception in interpersonal communication.

For each of the two contexts (with and without mirror) conducted in the main experiment, we calculated the difference between each participant's scores of conversational performance (see Figure 8) from the average scores of external scoring of the *Rubric for Public Speaking*. We refer to these calculated values as "score differences." We calculated the score differences for all scales in each of the areas of the performance of participants' conversational task (*Content*: 5 scale, *Delivery*: 5 scales). Since Likert scores of all participants are approximately normally distributed, we applied *Paired Samples T*

Test to evaluate whether the scores of each scale with and without mirrors were significantly different.

4.2.1 Content. The results of all five scales of *Content* are shown in Figure 8. There was no significant main effect of mirror on any of the five scales; Except *States the purpose*, the mean score of all the 4 scales of *Content* in the condition without mirrors is higher than that with mirrors.

4.2.2 Delivery. The results of all five scales of *Delivery* are shown in Figure 8. There was a significant main effect of the mirror on *Demonstrates awareness of the listener's needs* ($t = -2.306, p = 0.031 < .05$); the score difference of mirror (Mean = 2.682) was significantly lower than that of the score difference in conditions without mirror (Mean = 3.068). There was also a trend for the score difference with mirror in *Speaks clearly with appropriate vocabulary and information* to be lower than that without mirrors ($p = .083$), but the results were not significant. The mean score of 4 scales of *Delivery* in the condition without mirrors is higher than that with mirror, except for *Appears comfortable with audience*, with mirror ($M = 2.795, SD = 0.996$) and without mirror ($M = 2.705, SD = 1.241$). The scale of *Appears comfortable with the audience* is related to the appropriate use of body language.

4.2.3 Self-Evaluated Performance. After the main experiment, we asked participants to choose which condition made them have more *confidence*, *satisfaction*, *less anxiety*, and *more appropriate in their use of body language* in their performance among *mirror, no mirror*, and *the same for the two conditions*. In all four areas of self-evaluated performance, most participants selected the condition with a mirror as the condition where their performance was reported as more confident, satisfied, anxiety-relieving and using nonverbal cues more appropriately. The distribution of responses is shown in Figure 9.

4.2.4 Participant Perception of the Influence of Mirrors on Conversational Task. When asked to evaluate their conversational performance after the main experiment, most participants reported that they performed better with mirrors. However, there were also 9 participants who believed they performed better without mirrors. It can be seen that people's attitude towards the influence of mirrors on interpersonal communication is mixed. These themes are composed of data that explains how the participants evaluated the effectiveness of mirrors for their conversational performance in the main experiment.

Mirror Provides Feedback on Body Language for Social Appropriateness. Participants reported doing better and feeling more confident in conversing in the presence of mirrors because mirrors provide feedback and coordinate with body language better, helping participants better express themselves. Eight participants mentioned that without mirrors, there would be no real-time feedback and would lack the degree of control over postures. Also according to P21, *"As mirrors can reflect movement and know what you are doing, I was more confident seeing my real-time feedback from the mirror and to use body language more appropriately."* In addition the ability to make the expression of body movements in line with psychological expectations, participants also mentioned that the feedback of mirrors can give them more inspirations and ability to express their ideas. P3 said, *"Without a mirror, I may not be able to have a very concrete inspiration, but with a mirror I might be able to reflect some*

of my presentation movements. In this case, I feel better when I have a target, a point of visual focus, in front of me." According to this, in conversational performance, participants thought looking at their avatars in the mirror gives them a better sense of focus.

Mirror Serve as a Buffer for the Line of Sight During Conversation. Participants believe that mirrors can be used as a visual buffer in interpersonal communication through which they can look at each other and avoid the embarrassment of direct gaze. Six participants explicitly said talking with others facing a mirror reduces the tension of looking directly at the person they were talking to, making it more relaxing. But this communication model does not seem to work for everyone. Whether or not the mirror acted as a buffer to ease the pressure of direct gaze in VRChat seems to be related to individual social patterns. P3 and P7 mentioned they would prefer to look directly at each other when speaking in reality, so they do not avoid looking directly at each other in VR. P7 also shared, *"I prefers face-to-face communication with familiar friends. However, in terms of communication with strangers, I don't like to look directly at each other."* So we speculate that mirrors are more useful as a visual buffer for those who have a fear of social interaction when they have to socializing with strangers.

Focusing on Avatar Performance in the Mirror Brings Distraction. Although subjectively, most participants thought mirrors had a positive effect on their self-perception when they were talking, nearly half of participants said the reflection in mirrors distracted them from focusing on communication. Five participants thought that the appearance and actions of the avatar in the mirror would be a distraction for their conversational task. P14 revealed, *"If there is a mirror, I can't help but look at the mirror to see what I look like in the mirror, and it would be a bit distracting."* P6 also highlighted, *"If there is a mirror with an avatar in it, I will unconsciously look at it, which may not make my thought process so smooth."* In addition to feeling distracted during the performance of conversational tasks, it seems that participants also feels distracted by mirrors in daily social situations in front of mirrors. For example, P6 indicates that there may be distraction when chatting in front of the mirror in the usual game, not just during the experiment. The distraction that the mirror brings to participants seems to come from the fact that the attention to avatars in the mirror affects their own ongoing social activities. This appears to be especially clear when new avatars are used. P12 and P10 indicate that they were more distracted during the conversing process because they were unfamiliar with the avatar and it increased their attention to the avatar in the mirror, which may interrupt them from focusing on the conversational task.

Without a mirror to attract attention, participants also reported paying more attention to content and delivery of their conversational task. Three Participants thought they would focus more on the conversation itself and the communication with the person they were talking to when there was no mirror. According to P5, *"Without a mirror, I would focus more on the speech to listeners, and could get a sense of feedback. I also felt that I had more body language, which made it easier to express myself."* P20 also explained, *"When the mirror is turned off, it feels more interactive with the listener, and I can focus more on getting the point across."*
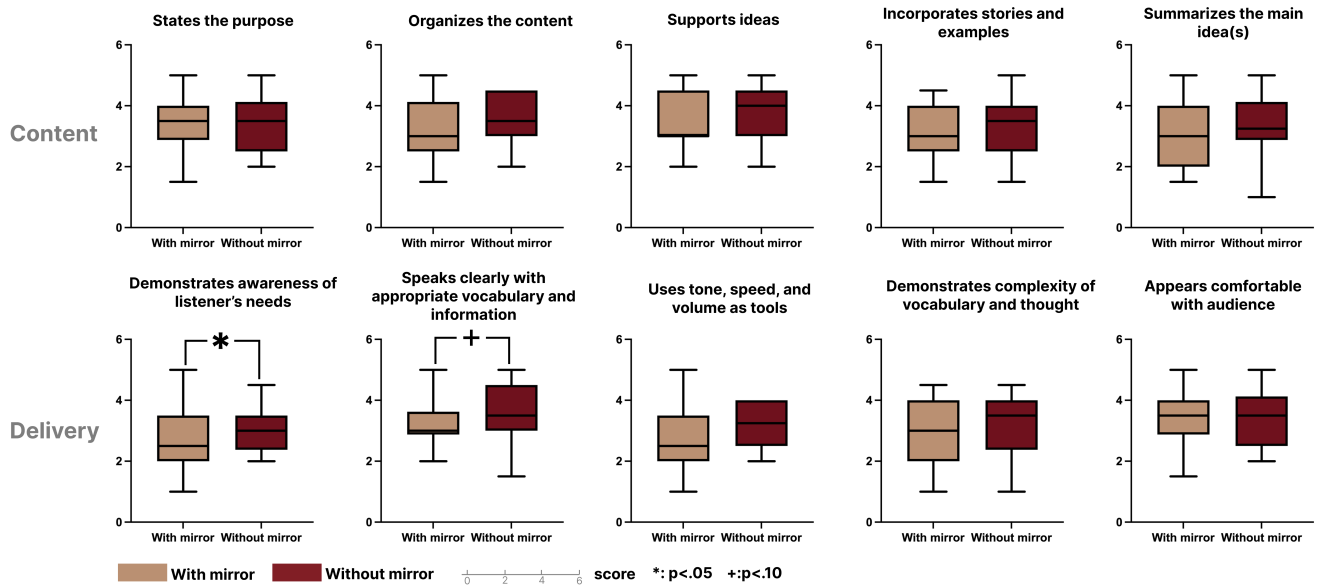
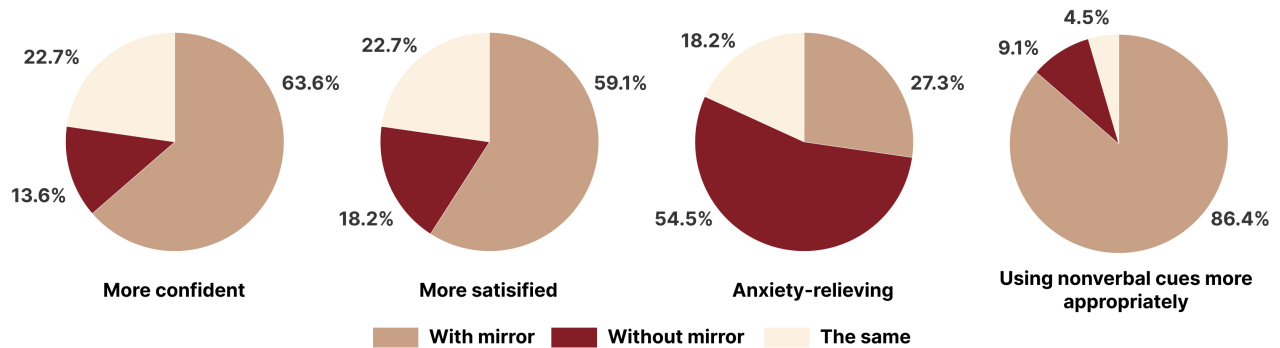**Figure 8: Scored ability on the 10 items in the PSCR rubrics for measuring conversational performance**

Figure 9: Self-evaluated comparative performance in mirror vs. non-mirror conditions along four dimensions of perceptual evaluation.

5 DISCUSSION

In regards to **RQ1** (*How do users behave and perceive themselves in the context of mirrors in social VR?*), we found that people are habitually attracted to gather in front of mirrors to chat and carry out activities, such as dancing, taking photos, or stepping away from keyboard (AFK) [1] to wait for interaction with others. Because players appear anonymously as users and are free to choose their avatars, some behaviors in front of the mirror are more daring, exceeding the norms of reality. In addition, the mirror also provides basic functions such as providing a wider background vision and calibrating avatar and body movements. Users of VRChat felt dependent on the mirror and thought it enhanced their sense of self and relieved their anxiety in social VR. In line with our findings,

we aim to analyze more mechanistically the unique role of mirrors in enhancing the embodiment illusion of users.

In regards to **RQ2** (*How do mirrors influence users' conversational performance in social VR?*), participants under the condition of mirrors-off scored higher than mirrors-on in 8 out of 10 items in the PSCR speaking rubric. The mean score of *"Demonstrates awareness of the listener's needs"* is significantly lower with the mirror active. *"Appears comfortable with audience"* is the only item where mirrors-on scores higher than mirrors-off on average. Somewhat at odds with the performance scores, more players believed they perform better with a mirror, with reportedly more confidence, greater satisfaction, less anxiety, and more proper use of body language. According to the follow-up interviews, there are two major points related to their better self-perception with mirrors: (1) Participants

feel more confident and satisfactory with mirrors because it provided synchronous feedback of their nonverbal language; (2) For introverted users, mirror can relieve stress anxiety of talking, as it acts as a buffer for player's own vision to avoid the direct gaze at the listener. As for conversational performance, about half of the participants said that they felt focusing on the avatar through mirror distracted them and made them less focused on the content and delivery. This suggests that the feedback provided by the mirror has both positive and negative aspects. On one hand, the ideal embodiment illusion and adjustments to the body language lead to better self-perception. However, the mirror in social VR also have similarities with self-view in online meeting, so that the feedback causes a greater cognitive load and results in poorer performance.

Having probed the influence of mirrors in social VR, we next discuss the implications of our work for extending the current understanding of interactions between mirrors and avatars, our reflections on the connection between the interview and quantitative studies, and our proposed design considerations in hope of mitigating the negative effects in mirror-related social behaviors.

5.1 Effects of Mirrors and Avatar Interaction on User Perception and Behavior

As noted earlier, the prevalence of mirrors and mirror-related social phenomena have drawn considerable attention from the game community. However, few empirical studies have explored the phenomena and potential explanations behind them. Therefore, by connecting to findings on mirrors and avatars in the psychology literature, our findings extend the understanding of psychological effects of mirrors in real life to the field of social VR. In addition to the psychological effects on user perception, we also discuss the unique behavioral patterns brought about by mirrors in social VR, in conjunction with the use of avatars.

5.1.1 Self-Awareness, Embodiment, and Self-Assessment via Mirrors in Real Life and Social VR. Our findings relate the theories of self-awareness in real life with embodient in VR. We also point out the nuances of mirrors as self-assessment tools in social VR.

Mirrors in real life and social VR have the common functions of constructing self-awareness and enhancing embodiment. Our interview findings are consistent with Lacan's *mirror stage* theory, which suggests that mirrors in real life enable people to generate an awareness of selves by looking at themselves in the mirror. In our interviews, participants also noted that mirrors in VRChat help reinforce who they are in the virtual world with their virtual body, enhancing their virtual identities, embodiment, and body ownership illusion (BOI) [44]. When turning on the mirror, users can see the reflections of their avatars, leading to a feeling of their own body being substituted by the avatar. In addition, users can also see that their movements in the mirror are in sync with real-life movements, which enhances their embodiment in VR.

Our findings also align with prior work on mirrors in real life as a self-assessment tool, correcting people's imaginative negative mental image of themselves. According to Clark and Wells [59], objective feedback of mirrors on how they perform in social settings may correct their negative self-perceptions [74]. Similarly, our participants mentioned that mirrors in VRChat enable them to check the presentation of their avatars, which can often appear strange

due to asynchronous facial expressions and non-verbal language resulting from the inaccuracy of their devices.

However, compared to mirrors in real life, users are particularly obsessed with looking into mirrors in VRChat, due to the flexibility of self-presentation with avatars. Unlike in real life, there is no negative mental image to correct in social VR. Avatars of users' own choosing already represent their ideal mental image, even though users would use mirrors to check whether their avatars are properly presented. Since VRChat is a user-generated content platform that allows users to create avatars with high customization, many users would gather in front of mirrors to appreciate the avatars and their customized features such as changing outfits. Whereas in real life, as noted by our participants, people do not appreciate themselves in the mirror for a long time unless they are well dressed up, which could also take much longer than simply switching to their preferred avatars. As a consequence, the greater flexibility and ease of self-presentation enabled by avatars lead to common and almost obsessive usage of mirrors in social VR in comparison to real life.

5.1.2 Behavioral Patterns in Front of Social VR Mirrors Compared to Real Life. Here we discuss the previous theories of the Proteus effect and avatar anonymity in light of our results, to explain how unique patterns of behavior which are not common in reality emerge in the context of mirrors in social VR.

The Proteus effect [35, 94, 96] indicates that the use of embodied avatars leads to behavioral and attitudinal changes. In social VR, the Proteus effect can be experienced in a more embodied manner due to the direct connection between one's physical self and the avatar through the body tracking system [35]. We infer that mirrors in social VR serve the role of driving the Proteus effect. Previous studies indicated that only a brief exposure to the virtual mirror can shape our behavior measurably such as in tasks like being intimate with more or less attractive avatars [94]. Since mirrors can be seen everywhere in social VR maps, the exposure to the mirror is continuous and easy to access, which means the Proteus effect can be constantly driven and enhanced. Secondly, reinforced by this continuously accessible Proteus effect, the ideal embodiment continues to influence and shape the behaviors of users, enabling participants to have a more confident mindset and bolder behavior, thus making them more willing to socialize.

In addition to the Proteus effect driving more confident behaviors in social VR, the anonymity of avatars also shapes unique behaviors in social VR [16, 64]. Previous studies indicate that anonymous avatars also encourage more daring communication without having to worry about disclosing private matter [64]. Because of this anonymity, in our interview results, participants say they like to touch each other (Phantom sense), dance, and even engage in erotic role-playing in front of mirrors in public places, which are seldom seen in real life with social rules and regulations. Anonymity, immersion, and the lack of limitations in the social VR world also provoke us to think more about potential pitfalls. Previous studies showed that anonymity may lead to harassment to vulnerable groups and bullying of marginalized users [37]. Collective avatars have been used for the construction of a common identity and for trolling activities that often acquire aggressive and racist undertones [18]. It's worth reflecting on how to better regulate behavior

in social VR to ensure that anonymity brings confidence while reducing aggressive harassment behaviors.

5.2 Discrepancy Between Perception and Performance in the Context of Mirrors

Based on participant recollections of previous experiences with mirrors, it is clear that mirrors played a positive integral role in their VRChat experience. For one thing, the mirror plays a functional role in ensuring social activities occur smoothly in social VR. For another, when looking into the mirror, users establish a connection between themselves and their avatars, forming a digital representation of themselves [32, 47, 79, 92]. Moreover, appearing in an ideal embodied avatar in front of mirrors leads to a continuous positive emphasis on embodiment illusion, which makes users like introverted people more confident and willing to communicate. Therefore, we hypothesize that the feedback provided by the mirror through an avatar-mediated interaction has a positive psychological effect on users and encourages interpersonal expression.

Consistent with this hypothesis, the self-evaluation results of the conversational tasks illustrate that most participants felt they had a higher perception level (more confidence, higher satisfaction, lower anxiety, more proper use of body language) with mirrors. Their believe the main reason is that the mirror provides body language feedback that allows them to be aware of their behaviors. Adjustments of behaviors and appearances of avatars in front of the mirror make objective conversational performance more in line with psychological expectations, consistent with research findings that mirrors provide feedback of objective information to correct untrue negative information, leading to higher self-awareness and reduced anxiety [53, 59].

According to previous studies, a higher level of self-awareness and satisfaction with the appearance in front of a mirror can lead to better performance [21, 74, 93], which makes it natural to presume that objectively scored conversational performance will also be better when there is a mirror. However, the objective speech rubrics ratings seem inconsistent in general with better conversational performance. In other words, the positive psychological effect brought by the mirror does not appear lead to better elaboration and communication performance. However, a closer look at specific scores shows that only "*Demonstrates awareness of listener's needs*" scores are significantly higher without a mirror, which is consistent with the effect of a mirror being distracting to the conversation-making process, because the participant is paying attention to the avatar as opposed to the listener.

Chatting in front of a mirror is similar to video conferencing, where you can see your own performance through a mirror (or self-view) while also seeing the other person's reaction and feedback at the same time. Previous studies on self-view have shown that both comparisons to true and ideal selves [10, 26], and paying attention to the appearance presented in self-view, increase cognitive load [10] and lead to distraction, lower satisfaction, and reduced productivity. Because of the similar communication and the feedback function, we speculate that mirrors in social VR have the same impact on interpersonal communication as self-view in teleconferencing. It can be revealed from the interview results of the conversational task that focusing on the avatar's performance

in the mirror would be distracting. They would think about whether the avatar's performance was reasonable and thus neglect to focus on the conversation itself, which seems to be especially true in impromptu communication that requires concentration. Also, unlike teleconferencing, social VR has greater use of body language, and thus synchronization of avatars may also distract users from focusing on the content and delivery in conversation.

Above all, we suppose that the positive psychological impact of appearing as an ideal embodied avatar is the main reason why participants prefer to chat and interact with others in front of mirrors, allowing them to gradually become "mirror dwellers." Nevertheless, while the mirror positively impacts nonverbal communication by providing feedback, it has potential to negatively impact verbal communication through distraction, since conversation requires a high level of concentration.

Mirrors play an irreplaceable role in enhancing entertainment in VRChat, but there is potential to cause negative effects. While VRChat focuses on enhancing social interaction, creative activities, and avatar customization, other social VR platforms such as AltspaceVR focus more on communicating with others through chat, event attendance, and professional development [35], making it crucial to avoid the possible negative effects of mirrors on interpersonal communication there. As social VR application scenarios continue to develop, activities like live streaming [22], exhibitions [23], and language learning [25], will continue to emerge in social VR. With an increasing need for more focused attention during interpersonal communication, it is essential to optimize mirror settings to avoid possible distractions.

5.3 Design Considerations for Social VR

Based on our findings, we identified three design implications to enable mirrors to better enrich user social experiences and avoid potential drawbacks.

More Flexible and Optional Mirrors. Our research indicates that mirrors are integral to the social gathering experience in social VR, supporting unique social activities like dancing and taking pictures. Specific interview results show that mirrors are one of few interactive objects in VRChat, since they can be open or close, and change display quality. Are there other features that can make mirrors more interactive? For example, the mirror border design can be made to fit different thematic scenes rather than just a flat surface, thus making it more motivating for users to interact with for taking pictures with their friends. We also suggest that the mirror can be scaled or rotated to meet different functions, not just fixed in size and position as it is currently. For applications to dance performance, high-quality, large mirrors uncommon in VRChat are needed to see both audience and players clearly. Beyond functional needs, more flexible mirror settings such as taking different shapes and material properties induce greater interaction from players, so the mirror can be regarded more as a tool rather than a place. Interactive mirrors can potentially reduce the distraction associated with self-view [10], since it would only be used when needed, rather than a constant source of attention. Interactive mirrors can also better support functions like looking at a background view and fine-tuning calibration assistance that are demonstrated to be essential to users in our study, since they can be moved and adjusted in place.

Even though participants can now pull up mirrors which are only visible by themselves from the menu (local mirror), we think it is also necessary to bring up mirrors through settings from the menu that can be seen by others (public mirror). This is because in addition to single-person interaction in front of the mirror, multi-person interaction is critical to the socialization process. Such a setting can meet the needs of users anywhere whether they have a need for public or personal use.

Modifying Mirror Availability in Social VR Locations Depending on Function. With many participants mentioning the importance of adjusting the appearance of the avatar in front of the mirror as part of the embodiment process, we suggest placing a mirror at the starting point of the map to facilitate full body calibration or adjustment for adapting to different maps. In addition, because mirrors have the role of concentrating players on the map, avoiding placing mirrors in the centre of the competitive game map can help to prevent the concentration of players away from the keyboard, which would reduce the interactions of players.

With the continued development of social VR and autonomous creative platforms like VRChat, activities like live streaming [22], exhibition [23], language learning [25], and online teaching in social VR are gradually emerging. In the study, we found that mirrors, in conjunction of avatar-use, may take attention away from player, reducing their conversational performance, we recommend that designers avoid the excessive presence of mirrors in places where focus of attention is required. This would include activities like exhibitions and online teaching, where otherwise users would be distracted by avatars away from the task at hand.

More Accurate Facial and Full Body Tracking. Early work has supported the claim that highly realistic avatars with real-time facial forms are critical to virtual environments [14]. Moreover, subtle errors can change the interpretation of the action in social interaction [52]. Our results show that appearing in front of mirrors is necessary for confirming facial expressions and whether the action and real-life behavior are accurately synchronized. When players talks to one another in front of mirrors, more asynchronous body movements would contribute to higher embodiment and better user experience [45]. Increase the asynchronous level of VR headsets is especially important with facial expressions, which is the least accurate of the interactions. Future possible solutions may come from the use of predictive machine learning tools to enable realistic full-body tracking for embodiment of the avatar, so as to ensure a better avatar experience for users in social VR. Furthermore, VR platforms like VRChat are media for increasingly diverse social activities, which would drive the demand for more accurate facial and body tracking to make interactions in front of mirrors involving more nonverbal cues and better feedback to provide a more expressive and smooth user experience.

5.4 Limitations and Future Work

We note several limitations and future improvements of our study that should be considered when interpreting this work.

(1) In response to our research question, we hoped to explore the impact of mirrors on communication by using a quantitative study of conversational performance. In order to ensure that the mirror is the only variable in the quantitative study, avatars and an environment undisturbed by other elements needed to be strictly controlled. Although we have uploaded our experiment scenes to VRChat as part of the game and invited players to join in the form they are familiar with in VRChat, the controlled environment also has the potential to make participants behave unnaturally compared to typical VRChat interactions. Talking with a confederate who is a stranger may also influence participants' feelings, in turn altering the scored conversational performance compared to typical scenarios. However, taking to strangers is also a common condition to encounter in VRChat.

In terms of the avatars selected, we provided two avatars with different genders (male, female) instead of unisex avatars for participants to choose from. This was intended to aligns with participants' self-gender perception and also to promote a more natural experience [35, 45]. However, some social VR users perform as a new or different self (e.g., cross-gender play) immersively, so the presence of a transgender or gender-aligned avatar may affect participants' perceptions as well as performance in front of mirrors.

(2) The interview was arranged after the experiment so that the environments of the two conditions (with or without mirrors) were still fresh in the minds of the users. Thus, it was inevitable that the interview results about the experience part may have some exposure bias because the experiment was conducted first.

(3) The semi-structured and go-along interview of social VR in our study are essentially self-report findings, which may not be able to uncover what participants do when they are not observed by experimenters. To better investigate people's experience related to mirrors, more observation studies are needed in the future to naturalistically investigate users' behaviors in front of mirrors. For observational studies, we may create an account and spend time in open public spaces incognito to examine leisurely behaviors and interactions related to mirrors. We can record the timestamp of the observation in front of mirrors along with detailed narration of the activities and interactions [64]. Since VRChat may be a personal activity for many users, the especially expressive, taboo, non-normative behaviors engaged by participants may better be uncovered in naturalistic observation.

(4) Our study is based on collected data from a young cohort of Chinese native speakers whose social patterns may have unique characteristics. For example, they could be more reserved and introverted due to cultural background, which means they are less socially active. Most of them are overwhelmingly fans of particular subcultures, and tend to associate with people who are fans of this type of culture. As people from different cultural backgrounds may have different social patterns in social VR, future work should aim to recruit a broader participant pool with more diverse cultural backgrounds to capture a more comprehensive picture of social VR experiences related to mirrors.

(5) Our study was only conducted on VRChat. Different social VR platforms have different avatar autonomy and designs, as well as different social features, such as special functionality for entertainment or virtual meeting purposes, which may affect the role of mirrors have [55, 64]. Therefore, further research needs to be developed in more diverse social VR platforms such as Recroom, AltspaceVR, etc. to compare and deepen the understanding of social interaction in the immersive virtual world.

(6) Although most of our participants in this study are aged from 18 to 24, the largest age group of users [9] in VRChat, we still feel the need to investigate the effect mirrors have on multiple age group in future work. In particular, older adults may not use social VR in the same way, and may, for instance, perceive the role of mirrors to be functional rather than expressive.

(7) Our participants are all VRChat players with VR headsets, allowing them to afford more complex and diverse non-verbal communication than PC players. People in immersive virtual worlds are also more susceptible to spatial influences than in 2D online worlds [89]. Above all, whether mirrors have a different meaning for PC players or VR players needs further investigation.

(8) In future work, we would like to increase the sample size of quantitative experiments to meet adequate statistical power, while representing a comprehensive demographic of interest.

6 CONCLUSION

Commercial social VR applications such as VRChat have become increasingly popular digital social spaces offering embodied interactions that goes beyond real-life spaces. Players in VRChat appear to have unique adaptations to mirrors, which influence social behavior and perception through avatar-mediated communication. Our findings suggest that the influence of mirrors in social VR are:

(1) Emphasizing the ideal body illusion, enhancing positive self-awareness, and encouraging bolder behaviors; (2) Providing feedback to ensure consistency between incarnation and reality, making the experience more immersive; (3) The mirror cluster effect creates a unique culture in social VR, supporting fun interactions.

We have summarized the unique communication and behavioral patterns of dedicated users in social VR using avatar-mediated communication in front of mirrors. This unique phenomenon was explained in the context of previous literature, and the work fulfills the need for a study of the role of mirror in social VR. By exploring the most communicative interaction of conversational performance, our study reveals the positive effect the mirror have on self-perception in interpersonal communication, as well as the trend of negative effect on objectively scored verbal performance. We explained this discrepancy based on previous mirror theory, showing avatar distraction as a possible explanatory variable, making up for the relative lack of quantitative research on synchronous voice chat in social VR. Finally, we showed how spatially-based influences such as mirrors can differ in physical and digital worlds, uncovering unique strategies and adaptions adopted by humans in novel interactions in virtual vs. physical spaces.

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A   ADAPTED RUBRIC FOR PUBLIC SPEAKING

Circle one number (1-5) for each category. Add the total and divide by 10 for an average.

Content

		High		Average		Low
1	States the purpose.	5	4	3	2	1
2	Organizes the content.	5	4	3	2	1
3	Supports ideas.	5	4	3	2	1
4	Incorporates stories and examples.	5	4	3	2	1
5	Summarizes the main idea(s).	5	4	3	2	1

Delivery

		High		Average		Low
6	Demonstrates awareness of listener's needs.	5	4	3	2	1
7	Speaks clearly with appropriate vocabulary and information.	5	4	3	2	1
8	Uses tone, speed, and volume as tools.	5	4	3	2	1
9	Demonstrates complexity of vocabulary and thought.	5	4	3	2	1
10	Appears comfortable with audience.	5	4	3	2	1

Explanation of Public Speaking Rubric
Score on a scale of 5 to 1

Use whole numbers only. Below are descriptions of some of the range. A score of 4 or 2 are in the middle. For #1, for example, a "4" would be "somewhat" clear; a "2" would be somewhat evident but not entirely. Please print out and use the rubric above, circling the applicable numbers.

Content

1. States the purpose.

Points	Criteria
5	The purpose is clear and captures the listener's attention.
3	The purpose is apparent.
1	The purpose is not evident.

2. Organizes the content.

Points	Criteria
5	The content is organized logically with fluid transitions to capture and hold the listener's attention throughout the entire presentation.
3	The organization of the content is congruent; transitions are evident.
1	The content lacks organization; transitions are abrupt and distracting.

3. Supports ideas.

Points	Criteria
5	Important details add to the interest and depth of the presentation;
3	The speaker provides the basic details necessary for the listener to understand the premise of the presentation.
1	The majority of ideas are unsupported by additional information or explanation.

4. Incorporates stories and examples.

Points	Criteria
5	Relevant examples or stories work to interest the listener and further develop main ideas.
3	Stories and examples obviously relate to the content of the speech.
1	Stories and examples are missing or unrelated.

5. Summarizes the main idea(s).

Points	Criteria
5	The conclusion unites the important points of the presentation and encourages future discussion.
3	The conclusion summarizes the main ideas.
1	The speech ends without a summary.

Delivery

6. Demonstrates awareness of listener's needs.

Points	Criteria
5	The choices of language, examples, and aids work together to heighten the listener's interest and connection to the topic.
3	The speaker's word choices, explanations, and enthusiasm are appropriate, for the topic and for each point appropriate aids are incorporated.
1	The presentation is uninteresting.

7. Speaks clearly with appropriate vocabulary and information.

Points	Criteria
5	The vocabulary is descriptive and accurate engaging the listener through imagery.
3	The vocabulary provides clarity and avoids confusion.
1	The vocabulary is awkward or inappropriate for the topic making the speaker difficult to understand.

8. Uses tone, speed, and volume as tools.

Points	Criteria
5	The speaker manipulates tone, speed, and volume, usin these tools to emphasize important ideas and hold the listener's attention."
3	The speaker avoids distraction vocal fillers or physical mannerisms and uses adequate speed and volume throuhout the presentation.
1	Vocal fillers are present throuhout the presentation. Speed and volume are inappropriate for the presentation.

9. Demonstrates complexity of thought and vocabulary.

Points	Criteria
5	Variation of sentence structure and word choice works to keep the listener interested and provides multiple examples and descriptions.
3	Sentence structure and word choice are varied to avoid monotony of tone and repetition of ideas.
1	Repeatedly expressing the same idea, repetition of vocabulary.

10. Appears comfortable with audience.

Points	Criteria
5	Eye contact, interaction with aids, and physical gestures demonstrate the speaker's energy and interest, guiding the listener through the presentation.
3	Eye contact, interaction with aids, and physical gestures are natural and fluid.
1	Eye contact with the audience is lacking. Gestures are missing or awkward.

Semi-structured interview outline

Experiment-related

1. Which condition do you think is the best to state your opinion (idea), and Why?

2. Do you feel that body language helps you express yourself better in VRChat?

3. In which situation do you think you used body language more appropriately?

4. In which situations do you feel more confident when you are presenting your ideas?

5. In which situation are you more satisfied when you present your ideas?

6. In which situations do you feel more anxious and nervous about speaking? Why?

7. If you were given the same conditions in real life, do you think you would feel and act the same way as you just did?

Mirror-related experiences in social virtual reality

1. In VRChat, how often/frequently do you make new friends, talk to people, socialize with others, etc. in front of a mirror?

2. Under what circumstances do you typically appear in front of a mirror?

3. What do you generally like to do in front of a mirror?

4. People in real life don't usually gather in front of mirrors for long periods of time to talk, but people in VRChat do like this. Can you explain why based on your own experiences and thoughts?