"Grab the Chat and Stick It to My Wall": Understanding How Social VR Streamers Bridge Immersive VR Experiences with Streaming Audiences Outside VR

Yang Hu
School of Computing
Clemson University
Clemson, South Carolina, USA
yhu3@clemson.edu

Guo Freeman
School of Computing
Clemson University
Clemson, South Carolina, USA
guof@clemson.edu

Ruchi Panchanadikar
School of Computing
Clemson University
Clemson, South Carolina, USA
rapanch@clemson.edu

Figure 1: How social VR users stream their activities and experiences in immersive social VR spaces for online audiences outside VR to watch (left to right: a streamer in the offline world, the streamer's avatar in social VR with other social VR users' avatars, audiences on 2D streaming platforms watching the streamer's activities in social VR in front of a screen outside VR)

Abstract

Social VR platforms are increasingly transforming online social spaces by enhancing embodied and immersive social interactions within VR. However, how social VR users also share their activities outside the social VR platform, such as on 2D live streaming platforms, is an increasingly popular yet understudied phenomenon that blends social VR and live streaming research. Through 17 interviews with experienced social VR streamers, we unpack social VR streamers' innovative strategies to further blur the boundary between VR and non-VR spaces to engage their audiences and potential limitations of their strategies. We add new insights into how social VR streamers transcend traditional 2D streamer-audience engagement, which also extend our current understandings of cross-reality interactions. Grounded in these insights, we propose design implications to better support more complicated cross-reality dynamics in social VR streaming while mitigating potential tensions, in hopes of achieving more inclusive, engaging, and secure cross-reality environments in the future.

CCS Concepts

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

Keywords

Social Virtual Reality, Live Streaming, Audience Management, Online Engagement, Cross-Reality Interactions

ACM Reference Format:
Yang Hu, Guo Freeman, and Ruchi Panchanadikar. 2025. "Grab the Chat and Stick It to My Wall": Understanding How Social VR Streamers Bridge Immersive VR Experiences with Streaming Audiences Outside VR. In *CHI*

CHI '25, Yokohama, Japan

ACM ISBN 979-8-4007-1394-1/25/04
https://doi.org/10.1145/3706598.3713561

Conference on Human Factors in Computing Systems (CHI '25), April 26–May 01, 2025, Yokohama, Japan. ACM, New York, NY, USA, 19 pages. https://doi.org/10.1145/3706598.3713561

1 Introduction

Social Virtual Reality (VR) platforms (e.g., VRChat, Meta's Horizon Worlds, and RecRoom) are spaces where multiple users can interact with one another typically through VR head-mounted displays and immersive 360-degree virtual content in 3D virtual spaces [12, 18, 23, 47]. They have been praised for dramatically transforming online social interactions through enhanced embodied and immersive social experiences via full- or partial-body tracked avatars (i.e., one's avatar body actions correspond to one's physical body actions in real-time); predominate voice communication; body language and gestures; and simulated immersive activities [18, 47, 66]. As such, a growing body of HCI research has focused on various interaction dynamics **within** social VR [2, 3, 17, 35, 76, 77]. However, how social VR users also endeavor to make their activities and experiences in immersive social VR spaces available and viewable **outside** the social VR platform (e.g., through streaming to their audiences on 2D live streaming platforms; see Figure 1) seems to be an increasingly popular but understudied new phenomenon that continues to blend and innovate the current landscape of HCI research on both social VR and live streaming.

Indeed, we have seen a steady growth of streamed VR content on popular streaming platforms such as YouTube and Twitch (e.g., [67]), as well as more detailed guidelines and tutorials regarding how to set up VR streaming (e.g., [31]). Compared to traditional 2D live streaming, social VR streaming differs in two significant ways. First, traditional live streaming typically requires the streamer to sit in front of a computer/camera and interact with viewers via microphone, keyboard, and mouse. In contrast, social VR streamers focus on VR-specific embodied engagement. They often stand up and move around while wearing a VR headset to fully immerse themselves in the VR space through embodied identity practices (e.g., full- or partial-body tracked avatars) to generate the streamed content (Figure 1) [74]. Second, social VR streamers face unique technical and social challenges by blending cross-reality interactions in both physical and virtual worlds [74]. Such complexity often stems from leveraging various technologies to interact with multiple stakeholders across different realities (e.g., streamers in social VR, audiences on non-VR streaming platforms, and bystanders in social VR), which also requires streamers to navigate across interaction modalities in different realities (e.g., VR and non-VR user interfaces) [1]. As this emerging streaming practice continues to shape new forms of online social experiences that creatively combine immersive VR activities with interactive non-VR live streaming, we believe that more in-depth investigations of social VR streamers' nuanced practices and their struggles are crucial for better understanding more complicated cross-reality social dynamics in the future.

In this paper, we specifically explore the following research questions using 17 in-depth semi-structured interviews with experienced social VR streamers:

RQ1: What unique strategies have social VR streamers used to bridge immersive VR experiences with their audiences on streaming platforms outside VR?

RQ2: How do social VR streamers perceive the potential limitations of their strategies?

We make two primary contributions to HCI research at the unique intersection of live streaming and social VR research. **First**, we contribute towards the growing body of literature on exploring more nuanced and immersive methods to transcend traditional 2D streamer-viewer interactions (e.g., [34, 55]). In particular, we unpack social VR streamers' innovative strategies to move beyond conventional 2D streamer-audience interactions by facilitating direct physicalized and embodied engagement and cross-reality interactions between streamers in VR and viewers outside VR on traditional live streaming platforms. On the one hand, these approaches go beyond merely verbal or non-verbal communications on a 2D screen [11, 33, 34, 58, 71] or specific outside-screen interactions [34, 55]. This allows social VR streamers to further blur the boundary between VR and non-VR spaces to engage their audiences through creating a sense of physical co-presence with their viewers, enabling viewers' tangible involvement in VR, and expressing a more genuine self. On the other hand, compared to existing research on cross-reality interactions, we also offer novel insights into how social VR streamers leverage even more creative and complex cross-reality strategies (e.g., natural, physicalized, and tangible interactions) to facilitate intuitive streamer-audience interaction across different realities. These practices thus significantly expand prior works on the commonly controlled workspace cross-reality settings (e.g., [27, 49, 54, 57, 65]). **Second**, we provide critical reflections on potential risks and limitations in social VR streamers' emerging practices built upon existing safety concerns in social VR (e.g., harassment issues [4, 5, 21, 59]), privacy risks such as identifying offline individuals through their full-body movement patterns in VR [50], and cross-reality interaction challenges (e.g., maintaining asymmetric awareness across realities [27, 49, 57, 65]). Grounded in these insights, we propose potential design implications for supporting social VR streamers' future endeavors while mitigating these identified tensions, which may contribute to a broader research context around safer and more nuanced cross-reality, hybrid social interactions in the future.

2 Related Works

2.1 The Importance of Self-Presentation and Streamer-Audience Interactions in Live Streaming

Live streaming is a unique interactive media form that combines both public broadcasts of high-fidelity live audio and video through the Internet and low-fidelity text-based communication channels for streamers and viewers [29]. Popular live streaming platforms and services such as Twitch.tv, YouTube Live, and Facebook Live have increasingly become a part of pop culture, attracting millions of viewers and streamers and offering a variety of streamed content ranging from gameplay, painting, crafting, eating, and cooking to sleeping [30]. This growing social phenomenon of live streaming has led to a large body of HCI research with diverse foci. Examples include understanding live streaming as a form of cultural heritage [26, 40, 52] and digital economy [32, 72], for learning and teaching purposes [9, 10, 13, 15, 28, 36], and a creative content creation community where moderation plays a central role [38, 39, 61, 62,

70, 73, 75]. Among them, how streamers strategically manage their live performance to engage with their audiences has become a key research agenda for understanding live streaming as a nuanced online social space for new interaction mechanisms and identity practices [11, 20, 26, 28, 29, 38, 55, 71, 72]. Taken together, previous research has highlighted several main strategies that live streamers have used to manage and engage with their online audiences.

First, streamers leverage both selective and authentic online identity practices and self-presentation approaches to orient how they can establish and sustain streamer-audience engagement. The practice of *selective self-presentation/ performance* origins from Goffman's metaphor of *theatrical performance* [25]. According to Goffman, self-identity is constructed in a collective and interactive process within different social settings, meaning that people are performers who adjust their "front-stage" presentation primarily based on audience expectations [25]. Therefore, it is important for performers (i.e., who endeavor to construct their self-identity) to identify audiences to adjust or customize their performance. In the context of live streaming, Virtual YouTuber streaming provides such an example of leveraging *selective self-presentation/performance* to engage with their audiences. As these streamers play as voice and motion actors behind virtual avatars, they usually perform according to designated personas and content guidelines bound to the avatars' settings [14, 41, 64]. In contrast, in webcam-based live streaming, some streamers tend to prioritize less audience/performance-oriented but more self-driven and *authentic* aspect of digital representations due to both the real time and high-fidelity nature of interactions in live streaming and streamers' desires to control their own bodies [20]. For example, women and LGBTQ streamers could intentionally manipulate visual and audio cues to express their offline identities and resist viewers' inappropriate expectations of their gender and sexuality [20]. As a result, streamers' "back-stage" identities (e.g., their private selves) eventually shift their "front-stage" self-presentations for their streaming audiences (e.g., their public streaming persona).

Second, built upon their online identities, streamers leverage both verbal and non-verbal communication to establish connections with viewers. On the one hand, due to the real-time nature of contemporary live streaming, verbal communication through synchronous text or voice chat serves as a primary strategy for streamers to engage with their audiences [29]. For instance, streamers can intentionally pace their conversations with viewers based on digital gifts or donations they receive from viewers [42, 72, 81]. Streamers can also adapt their chat management method based on diverse audience criteria and considerations [58, 71]. Examples include intentionally balancing general audience with interacting with a specific viewer, prioritizing certain viewers or topics, and choosing to engage with a random viewer [58, 71]. This selection process not only reflects streamers' personal preferences, but also requires recognizing viewer types and tailoring respective content according to different criteria, including gifting amounts, chat content, and frequency [58]. On the other hand, streamers also rely on a range of visual system features to engage with their viewers in varied non-verbal ways. Examples include using emoticons to quickly express audience emotions [58], leveraging channel-featured gift designs to attract attention and enhance connections between streamers and viewers who tip [33], and interactive UI overlays like poll results [11], and donation indicators [34]. These tools significantly supplement how streamers can connect with viewers by facilitating more immediate and specialized feedback on their audience's collective moods and attitudes across multi-model channels within or outside the streaming platform [11, 33, 58].

While these works paint a comprehensive image of streamers' existing efforts to engage with their viewers, they have also collectively pointed to a significant challenge: contemporary live streaming still lacks ways for streamers and audiences to convey rich social cues beyond text and visuals on a 2D screen [34, 55]. As online social spaces evolve towards more natural interaction, research on live streaming has also begun to investigate more nuanced and immersive methods of fostering streamer-viewer interactions and audience engagement. Such efforts tend to focus on introducing physiological interactions to help streamers engage with audiences beyond verbal or non-verbal communication. For example, Robinson et al.'s work used viewers' heart rates to affect the sound, lighting, and difficulty of a gaming stream [34, 55]. And Lessel et al.' research demonstrated novel methods that allow viewers to influence the streamers' environment (e.g., room lighting) and even the streamers' bodies (e.g., vibrations on their forearms) [34]. In line with this emerging research agenda, our work is motivated to investigate social VR streaming, an emerging new landscape that not only technically blends both VR and non-VR spaces but also facilitates cross-reality social interactions through this unique intersection.

2.2 Social VR Streaming as an Emerging New Online Landscape for Cross-Reality Social Interactions

Existing HCI research has begun to examine emerging social interactions across different realities (e.g., virtual, augmented, and physical), such as remote classrooms (e.g., mirroring physical classroom interactions in VR so a remote student can participate in such interactions [53]), remote expert instructions (e.g., a remote expert uses VR or AR to guide a local user to perform physical tasks [51]), and hybrid collaborative workspaces (e.g., users employ VR, AR and 2D interfaces for shared tasks [49, 57, 65]). Taken together, these works have highlighted several unique aspects of such interactions. First, cross-reality interactions often require asymmetric collaborative setups (e.g., different displays and interaction modes) between users in different realities (e.g., users in VR and non-VR working together) and may also require them to transit between different realities (e.g., transiting from VR to non-VR, or vice versa) [1]. Second, in addition to users who engage in cross-reality interactions, bystanders (such as other VR users besides the primary VR user) can be important stakeholders who provide spatial cues and social interactions that directly shape the primary users' overall cross-reality experience [1]. However, most existing research on cross-reality interactions has focused on experimental environments and predetermined interaction patterns. For example, in hybrid collaborative work settings, cross-reality interactions are typically constrained by specific tasks and facilitated through customized displays and tools [27, 49, 54, 57, 65]. In contrast, while social VR streaming shares

the asymmetric nature of cross-reality scenarios (i.e., between VR streamers and non-VR audiences), it features naturally emerging, complex, and embodied social interactions blending both virtual and physical worlds and across both 3D spaces and 2D screens. This thus makes it an especially challenging yet nuanced phenomenon to further extend our current understandings of cross-reality social interactions.

On the one hand, social VR streaming is uniquely built upon VR-specific embodied engagement. Prior works have highlighted how social VR provides a unique sense of *embodiment* (i.e., how we can experience a virtual body representation as our own body within a virtual environment [63]) in terms of self-location, agency, and body ownership compared to other conventional online social spaces [3, 16, 18, 19, 37, 79]. First, instead of relying on traditional input methods like keyboard, mouse, or joystick, social VR users use partially or fully body tracked avatars to explore the virtual environment in a more straightforward and immersive way, which creates a strong sense of self-location and awareness of co-presence [16]. Second, the wide use of verbal (e.g., voice) and non-verbal (e.g., body language) communication modalities in social VR further heightens one's agency of the virtual body [44]. Third, since one's avatar behavior in social VR corresponds to their body motions in the offline world in real time, it also leads to a higher awareness of body ownership because social VR users are not merely "viewing" their activities on screen but engaging in the virtual space with their physical body [16]. As a result, people seem to often form a more intimate and stronger bond between their physical body and their avatars (virtual body) in social VR than in other online contexts [18, 22]. Built upon such VR-specific embodied engagement, social VR streamers have to fully engage in immersive and embodied social VR activities because they are social VR users *per se*. This requires them to focus on performing full-body movements (e.g., dancing in social VR for viewers to watch) and actively interacting with other users within the social VR space, who may or may not be aware of their ongoing streaming practices. Meanwhile, they are also streamers and would need to strategically share their embodied engagement outside the VR space in real time.

Therefore, **on the other hand, compared to traditional streaming, social VR streaming leads to more complex cross-reality social interactions.** Above all, social VR streamers need to manage multiple parties across both VR and non-VR spaces. As such, they must navigate more technical complexities that combine both existing challenges in traditional live streaming and new difficulties emerging in social VR and cross-reality practices, including dedicated live streaming software (e.g., OBS), VR technologies (e.g., headsets, controllers, physical space preparation, and complex body tracking hardware), and cross-reality tools (e.g., specialized software like OVR Toolkit for accessing non-VR information while immersed in VR) [56]. Additionally, as they are streaming their activities for their audiences outside the VR space, they also have to attentively interact and engage with their viewers on streaming platforms at the same time. Bridging these two spaces requires them to simultaneously interact with people both in and out of VR, leading to complexities of how to seamlessly integrating disparate VR and non-VR experiences in their streams, such as activities in the VR space *and* chat on Twitch. For instance, Wu et al.'s analysis of 34 streaming videos on Twitch has highlighted VR streamers' common difficulties in establishing emotional connections with their viewers and maintaining streaming flow. The main reason is that when streamers wear the VR headset, they cannot directly control the streaming content or interact with viewers on Twitch chat [74].

Inspired by these nuances demonstrated in social VR streaming, we believe that more in-depth research is critically needed to explore how this new phenomenon has potential to transcend traditional streaming research in HCI and go beyond conventional streamer-audience interactions. Yet, only a small body of HCI work has begun to investigate this open space, such as Wu et al.'s work that only focuses on analyzing streaming videos, not streamers themselves, and therefore may not reflect VR streamers' own perceptions and solutions to manage and mitigate such challenges [74]. In this work, we aim to provide a deeper picture of how this new form of live streaming may shape future cross-reality social dynamics blending both virtual and physical worlds by directly interviewing experienced social VR streamers.

3 Methods

Recruitment and Participants. The university's Institutional Review Board (IRB) approved this study for research ethics. We then recruited participants who have live-streamed themselves engaging in social VR spaces (e.g., VRChat) in three ways. First, we directly contacted social VR streamers we already knew from prior contact and asked about their willingness to participate. Second, we identified popular social VR streamers on major live streaming platforms (e.g., Twitch) and invited them to participate. In hopes of including social VR streamers with diverse experience levels and popularity, we contacted streamers with various numbers of followers ranging from less than 1,000 to over 100,000 (see Table 1). Third, we also used a snowball sampling technique to recruit additional participants.

From October 2023 to July 2024, we interviewed every social VR streamer who was willing to participate in our study (N=17). Although our study's focus on the unique population of social VR streamers results in a relatively small sample size, our participants represent a diverse array of streaming experiences, genders, sexualities, ages, and races. We also believed that data saturation was achieved with this sample as no new major themes emerged in our final interviews. Table 1 summarizes participants' demographic information of their actual offline identity, and their social VR streaming experiences. While we collected information about participants' sexuality given our interest in the potential role of self-presentation and identity practices in social VR streaming, we found that participants' sexual orientation did not explicitly impact their current streaming practices. However, we include this data in this paper to offer further context for understanding social VR streamers' embodied identity performance, which serves as one of their main strategies to bridge immersive VR experiences with their non-VR audiences (e.g., avatar choices and roleplay behaviors). This may also inform future research on the intersection between more nuanced identity practices and social VR streaming. To protect streamers' privacy, we did not collect personally identifiable information (e.g., offline name) and used the ranges of their numbers of

P#	Gender	Age	Sexuality	Ethnicity	Social VR Platform	Streaming Platform	Number of Followers	Other Non-VR Content Streamed	Experience of Social VR	Experience of Social VR Streaming
P1	Man	25	Straight	Hispanic	VR Chat	Twitch	<1,000	N/A	5 years	4 years
P2	Trans Woman	26	N/A	White	VR Chat	Twitch	<1,000	Video Games	3 years	2 years
P3	Woman	26	Bisexual	N/A	VR Chat	Twitch	1,000-5,000	Video Games & Online Commentary	6 years	2 years
P4	Man	18	Straight	Asian	VR Chat	Twitch	<1,000	Video Games	3 years	2 years
P5	Woman	22	Bisexual	White	VR Chat	Twitch	1,000-5,000	Video Games	1.5 years	10 months
P6	Man	33	Bisexual	Black	VR Chat	Twitch & YouTube	1,000-5,000	3D Modeling & Video Games	6 years	3 years
P7	Non-Binary	36	Bisexual	White	VR Chat	Twitch & YouTube	1,000-5,000	Art & Video Games	1.5 years	3 years
P8	Gender Fluid	26	Demisexual	N/A	VR Chat	Twitch & YouTube	1,000-5,000	Video Games	2 years	5 months
P9	Woman	28	Lesbian	White	VR Chat	Twitch	10,000-50,000	Video Games	5 years	5 years
P10	Non-Binary	31	Biromantic Asexual	White	VR Chat	Twitch	1,000-5,000	Video Games	2 years	2 years
P11	Man	29	Pansexual	White	VR Chat	Twitch & YouTube & Kick	10,000-50,000	Video Games	5 years	5 years
P12	Non-binary	22	Bisexual	N/A	VRChat	Twitch & YouTube	1,000-5,000	Video Games	5 years	3 months
P13	Man	30	Straight	Asian	VR Chat	Bilibili	1,000-5,000	Video Games	2 years 8 months	9 months
P14	Woman	24	Straight	Asian	VR Chat	Bilibili	10,000-50,000	Video Games	2 years 4 months	7 months
P15	Gender Fluid	31	N/A	Asian	VR Chat	Bilibili	10,000-50,000	Video Games	5 years	3 months
P16	Man	20	Straight	Asian	VR Chat	Bilibili	1,000-5,000	Video Games	1 Year 2 months	3 months
P17	Man	23	Straight	Asian	VR Chat & Horizon Worlds	Bilibili & Tiktok	>100,000	N/A	2 Year 6 months	3 months

Table 1: Participants' offline demographics & online social VR streaming experiences. *N/A means participant information not provided.*

followers (<1,000, 1,000-5,000, 5,000-10,000, 10,000-50,000, 50,000-100,000, and >100,000) rather than exact numbers. These ranges aim to reflect our participants' diverse experience levels and popularity while maintaining their anonymity. Further, it is important to note that 15 out of 17 participants also actively streamed other non-VR content such as video games, art, and 3D modeling. Their rich experiences in streaming both social VR and non-VR content thus helped us further unpack what makes social VR streaming a unique context that requires novel strategies to engage with viewers.

Interviews. Before the interviews, we provided all participants with a consent document per participant preference (e.g., email or Discord). Upon consent, interviews were then scheduled and conducted via text or voice chat based on participant preference (e.g., Discord or Zoom). Interview questions were crafted using dialogic techniques designed to encourage participants to engage deeply with their responses [69].

The semi-structured interviews began with introductions, basic demographic questions, and questions regarding their level of experience with social VR platforms (e.g., VRChat, RecRoom, and Horizon Worlds) and live streaming generally. Then, participants were asked questions about their current practices and strategies to stream their activities and experiences in social VR spaces, especially compared to non-VR streaming (e.g., *"What are your strategies or methods for making streaming in social VR appealing to your viewers? What would you consider to be the main differences between streaming in social VR and streaming other types of non-VR content?"*). Next, they were asked how they would interact with their audiences, moderators, and other people in social VR while streaming. Example interview questions especially related to this study include: *How do you interact with people who watch your social VR streams? How often do viewers interact with you while streaming? How, if at all, do you feel that your interaction with people during your social VR streams is different from your interaction with people during your non-VR streams?* They were also asked to freely reflect upon any type of social or technical challenges they face when streaming in social VR spaces (e.g., *"What types of technological challenges have you faced when streaming in social VR, if any? How about non-technical challenges? And how did you address those challenges?"*). After that, they were encouraged to offer suggestions for better designing future VR and streaming technologies to address said challenges to support and innovate social VR streaming practices. Interviews lasted 64 minutes on average. Participants were paid with a $20 gift card after they completed the interview.

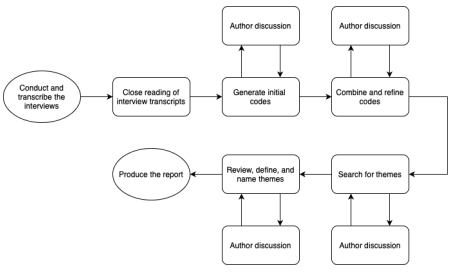

Figure 2: Overview of the data collection and analysis process in this study

Data Analysis. After the interviews were complete, recordings were transcribed for data analysis. We then utilized a thematic analysis approach [6, 7] to conduct an in-depth inductive qualitative

analysis of the collected data, as depicted in Fig. 2. A qualitative approach is appropriate for this study because qualitative methodologies are well-suited for investigating questions about "how people interpret their experiences, how they construct their worlds, and what meaning they attribute to their experiences" [48]. In particular, based on McDonald et al.'s guidelines for defining reliability in qualitative analysis in CSCW and HCI practice, our analytical procedures focused on eventually yielding concepts and themes (recurrent topics or meanings that represent a phenomena) rather than agreement [46]. According to McDonald et al, even if coders agreed on codes, they may interpret the underlying meaning of those codes differently [46]. Therefore, we did not seek inter-rater reliability in our analysis but endeavored to identify recurring themes of interest, detect relationships and connections among them, and formulate them into clusters of more complex and broader themes [46].

Following Braun and Clarke's [7] detailed guidelines for thematic analysis, we first *familiarized ourselves with the data.* The first author closely read through the participants' transcribed narratives line by line to take notes and identify information relevant to this study's research questions to gain a full picture of what social VR streamers usually do to engage their audiences outside VR with immersive experiences within VR. Second, we *generated initial codes.* The first author began an iterative coding process by assigning preliminary codes to identified information. Then, two authors combined the identified codes, eliminated redundant codes, addressed disagreements, and ensured that highlighted content only aligned with a single code. For example, the quote *"When my viewers trigger a certain gift, a steel tube will drop on my head, making a very loud sound. I will cover my head with my hands and say 'ouch.'"* was coded as "audience creating tangible objects in VR" and "more physicalized interactions between streamers and viewers," which were then discussed and combined into "physical objects redeem for tangible interaction." Third, we *searched for themes.* These two authors categorized codes into thematic topics related to our research questions and developed sub-themes from participants' descriptions. For example, codes about how various audible, visible and physical effects audiences can trigger in social VR were discussed and categorized as the theme of *tangible interactions to allow audiences outside VR to physically shape streamers' embodied experiences in VR.* We then *reviewed themes.* The two authors continued to address disagreements and discussed, integrated, and refined themes and sub-themes to best capture and represent our findings in relation to the research question. Next, we *defined and named themes.* All authors collaborated to refine these themes further and name the final set of themes [7]. Lastly, we *produced the report.* All authors selected the most compelling quotes as examples and logically drafted the structure of the findings [7].

4 Findings

Using quotes from participants' own accounts, in this section we explain four novel strategies that social VR streamers have developed to engage their audiences outside VR with immersive experiences within VR by leveraging social VR's unique interaction settings and technological features (**RQ1**). We also highlight these streamers' own reflections upon the potential limitations of each strategy that need to be addressed to offer more novel and immersive cross-reality experiences that further blur the boundary between VR and non-VR spaces (**RQ2**). It is important to note that in line with well established arguments against reporting qualitative data numerically (e.g., [45]), when reporting our findings, we focused on the actual themes we identified across the full dataset rather than a numerical accounting of the frequency of certain codes. The main reason is that quantifying qualitative findings can be misleading, as "[n]umbers can lead to the inference (by either the researcher or the audience) of greater generality for the conclusions than is justified, by slighting the specific context within which this conclusion is drawn" [45]. Therefore, rather than attempting to quantify our qualitative data, Table 2 provides a summary of our key findings to help capture the overall themes emerging in our data.

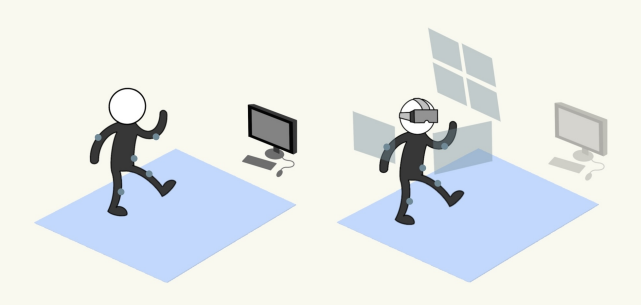

Figure 3: Left: In traditional, non-VR streaming with body-tracking, streamers must maintain distance from their physical display to avoid accidental collisions, potentially limiting their interactions with audiences. Right: In social VR streaming with body-tracking, streamers can move freely while keeping virtual audience inputs constantly visible, as virtual displays can be positioned anywhere in the VR space.

4.1 Strategy 1: Actively Tracking Full-Body Movements and Facial Expressions in Real Time to Naturally and Intuitively Engage with Viewers outside VR

Overall, our participants have unanimously identified actively tracking full-body movements and facial expressions in real time as the most crucial strategy for them to engage with their viewers outside VR for three reasons.

First, body tracking in social VR streaming makes streamers more accessible to their audiences compared to traditional, non-VR streaming. Notably, body and face tracking are not exclusive to social VR streaming. For example, virtual YouTubers have also used these tracking technologies to control their 2D or 3D virtual avatars in traditional streaming [14]. In contrast, P13 points out, *"In non-VR (streaming), when you dance or move your body, you have to keep away from your PC, so you won't break anything. This actually means that you cannot read from your viewers when you are moving. [...] However, VR is completely different. The chat window can float around and follow you, so you can always read and respond, even when you are doing acrobatic activities."* In this sense, social VR settings allow streamers to multitask, which means they can remain

RQ1: What unique strategies have social VR streamers used to bridge immersive VR experiences with their audiences on streaming platforms outside VR?	**Key Findings**
Strategy 1: Actively tracking full-body movements and facial expressions to naturally and intuitively engage with audiences outside VR	- Body tracking in social VR makes streamers more **accessible** to audiences outside VR. - Full-body tracking fosters streamers' **more active and physicalized** responses to audiences. - Facial tracking supports streamers' more **nuanced emotional interactions** with audiences.
Strategy 2: Using novel camera control to directly immerse viewers outside VR in 3D VR experiences	- Creative camera manipulation offers **immersive first-person experiences** for audiences outside VR. - Camera in VR becomes a **physical proxy** of viewers outside VR and allows streamers to **directly interact** with their audiences.
Strategy 3: Leveraging tangible interactions to allow audiences outside VR to physically shape streamers' experiences in VR	- Viewers can **trigger sound effects** that streamers can hear in VR space. - Viewers can **create 3D visual effects** in streamers' VR environments. - Viewers can **spawn 3D objects** in VR space that physically interact with the streamer's virtual body.
Strategy 4: Collaboratively roleplaying streamers' VR avatars to foster more personalized connections with their audiences outside VR	- Roleplay in VR creates various fictional scenarios and allows streamers to **showcase their personality** through various roles. - Streamers allow viewers to directly control their VR avatars or interact with other social VR users through their avatars, **building a unique streamer-audience co-play**.
RQ2: How do social VR streamers perceive the potential limitations of their strategies?	**Key Findings**
Limitation 1: Overly persistent and unstable tracking systems	- Persistent body and facial tracking may violate streamers' **personal privacy**. - Unstable body and facial tracking may cause viewers' **misinterpretation.**
Limitation 2: Overwhelming and glitchy camera control	- Camera management in social VR streaming can create **extra workload** for streamers. - Manual camera control in social VR can create **uncomfortable or interrupted** viewing experiences.
Limitation 3: Excessive and disruptive tangible interactions	- Excessive tangible interactions can lead to **chaotic and distracting** experiences for **streamers**, **audiences**, and even **other social VR users**.
Limitation 4: Challenge to manage interactions both in and out of VR	- Streamers struggle with **simultaneous interactions** with both viewers outside VR and other social users in VR roleplay. - Social VR roleplay can escalate the risk of **unwanted encounters** in VR.

Table 2: Summary of key findings

highly accessible to their audience displays (e.g., a chat window on Twitch) even when they have to fully engage in active physical performances (Figure 3). P14 further emphasizes, *"One reason I love dancing in VR is that I can be more connected to my viewers during my dance. [...] Unlike in non-VR streaming where I only read chat before and after my dances, in social VR, I can have a lot more back-and-forth talk (during my dances). [...] I sometimes even improvise my moves to respond to my viewers."* For P14, this enhanced accessibility seems to facilitate a more continuous connection between her audiences and herself, which further changes how she would perform and communicate with her audiences in social VR streaming (e.g., *"a lot more back-and-forth talk"*). Therefore, streamers like P14 not only feel more supported by their viewers in the moment but also are motivated to make their live performances even more interactive and creative (e.g., *"improvise my moves to respond to my viewers"*).

Second, full-body tracking in VR enables streamers' embodied and physicalized responses to audiences using body language in real time. For example,

"As opposed to stream non-VR content, I can react more animatedly with my movements in VR, as I have more hand movements and body languages instead of just talking." (P1)

"Because people can see and understand a lot of my body movements, I express a lot more with my body. As a result, I can show more about my expressions or reactions to my viewers." (P8)

As P1 and P8 reveal, for streamers, *"instead of just talking,"* they can express themselves *"more animatedly"* through body-tracking. This not only enables but encourages them to freely use body languages to express themselves and engage with their viewers outside VR. For viewers, these nuanced body languages help them to *"see and understand"* streamers without typing questions through

chat. As such, full-body tracking becomes a much faster (e.g., no need to type) and intuitive (e.g., naturally moving one's body) way to facilitate streamer-viewer communications across VR and non-VR spaces.

Third, participants further emphasize the importance of adding facial tracking to support nuanced emotional interactions with their viewers (Figure 4). P6 explains, *"Face tracking adds a whole new perspective to my VR stream. It makes me look genuine, and it really helps me to sell real emotions."* For participants like P6, facial tracking allows them to communicate with their audiences in a way that closely resembles offline, face-to-face interactions, such as using their avatar face to make *"genuine"* facial expressions during ongoing conversations. For them, this is crucial to creating emotional resonance with audiences outside social VR. P8 then summarizes, *"I felt social VR is a tool-ready and social inclusive platform, where I can freely show myself and just speak my heart out. Surprisingly, that resonates with a lot of people, and they have shown a lot of support for these streams."* In this sense, how social VR streamers track their body movements and facial expressions in real-time often makes them *"freely show myself and just speak my heart out,"* which further helps them engage with and even befriend their viewers outside VR.

Figure 4: An example of face tracking in social VR streaming

Strategy Limitation: Body and Facial Tracking May Violate Personal Privacy and Cause Misinterpretation. However, our participants also identify two main limitations of this strategy that may actually hinder their connections with their audiences: (1) *persistent tracking may violate social VR streamers' personal privacy*; and (2) *inaccurate tracking may lead to their non-VR audiences' misinterpretations and confusions.*

For **(1)**, although streamers' privacy concerns in live streaming is not new [39, 75], our participants unanimously argue that the body tracking system for social VR streaming can lead to much worse privacy issues compared to non-VR streaming. P9 explains,

"In non-VR live streaming, it is easier to just step away from the camera or use your PC to control the stream. However, in VR, the headset and trackers are physically strapped to you. They constantly record you, until you take them off or use the clumsy remote PC control in VR."

Here, social VR streamers have to physically adjust their tracking devices that are *"strapped"* to their bodies. Additionally, to configure their full-body tracking system, they have to *"use the clumsy remote PC control in VR"* rather than directly using the physical PC outside VR. Therefore, to avoid any downtime in their streams, social VR streamers often have to keep those trackers on their bodies all the time, which can potentially broadcast private personal activities that they do not intend to share. P9 then elaborates on an embarrassing moment when a social VR streamer may go to the bathroom with their tracking and microphone on: *"it is easier to forget turning off something, and others can know what you're doing [in the physical world]. One extreme example could be going to the bathroom."* P8 also specifically attributes this limitation to how social VR streamers are forced to fully expose themselves without any easy opt-out option during VR streaming: *"Comparing to non-VR streaming, there are a lot more that people can see and comment on (in VR streaming) [...] because I'm exposing my whole being, an honest reflection of my everything-moves, expressions, sounds-everything in my whole personality."* As a result, such persistent tracking can make social VR streamers feel vulnerable and unsafe, which in turn limits and harms their connections with their audiences outside VR.

Regarding **(2)**, the non-stop tracking in social VR streaming also comes with frequent technical instabilities. This makes the tracking inaccurate and thus confuses streamers' audiences. Several participants describe,

"When the tracking is lost, my hip can go flying off into the space, and my model bends over, which looks like a pretzel." (P11)

"After the tracking lost happens, you have to try to fix it, explain it and kind of restore the conversation, which can be frustrating." (P2)

In these stories, the unstable tracking occasionally causes streamers' VR avatars to behave in wrong ways (e.g., *"my hip can go flying off into the space"*), which misrepresents and interrupts social VR streamers' live performances and body languages. This also leads to audience misinterpretations because the tracking system fails to convey the streamer's actual intention. Furthermore, as P2 explains, when tracking problems happen, social VR streamers must stop their ongoing streaming activities, fix the tracking issue, and explain what happened to their audiences. This not only frustrates their audiences in the moment but also distracts the streamer from the natural flow of engaging with their audiences outside VR. Worse still, when some social VR streamers can detect and fix the tracking system immediately, others might not be aware of the issue until too late (e.g., *"Sometimes my face tracking breaks and I have no idea why it happens. It can be even worse, as sometimes I don't realize it is happening or has ever happened."* -P10). As a result, inaccurate tracking in fact can cause more miscommunications and misunderstandings between social VR streamers and their audiences outside VR, rather than connecting them together across VR and non-VR spaces.

4.2 Strategy 2: Using Novel Camera Control to Directly Immerse Viewers outside VR in 3D VR Experiences and Atmospheres

Another insight from our study is that participants have creatively controlled and interacted with the virtual camera in social VR as a key strategy to directly immerse viewers on 2D streaming platforms (e.g., Twitch) outside VR in 3D social VR experiences and atmospheres. Compared to traditional live streaming, social VR streamers especially highlight how they can move the camera as if it were the viewer's own eyes, fostering more interactive and

Figure 5: An example of a social VR streamer physically interacting with the camera in VR to create immersive first-person experiences for viewers.

immersive experiences for both viewers and streamers. P3 and P5 explain,

"I have a lot more freedom in VR than I do out of VR...For example, I can grab the camera and move around with my audience. I would say the best word to explain it is that you can be a lot more parasocial with your chat." (P3)

"Let's just sit here and chat. Look at the pretty trees. Look at the pretty moon behind my head." (P5)

As shown in these participants' accounts, for viewers, this creative use of virtual camera allows them to directly follow the streamer's virtual body in social VR. This thus creates a heightened sense of engagement for viewers without forcing themselves to actually enter a social VR space. For streamers, camera in VR also becomes a virtual representation of their audiences outside VR. As shown in P5's description, she could sit in a VR space with the camera by her side, which made her feel like siting there with her viewers outside VR to look at *"the pretty trees"* and *"moon"* in VR together. Through this camera, although the streamer and their viewers are situated in different spaces (e.g., within VR vs. outside-VR), they can create shared experiences that transcend the boundary between VR and non-VR spaces.

Therefore, all of our participants point out that they often physically interact with the camera during streaming, as if it was the viewers themselves, such as: *"When they're bullying me, I'll turn around, slap the camera, and say, 'No, silence, chat. Be nice'"* (P6). P6 also describes "drowning" his audience by humorously putting the camera underwater (Figure 5). Here, when streamers like P6 talk to and physically interact with the virtual camera in social VR, they are in fact talking to and physically interacting with their viewers outside VR. In P6's case, by directly *turning*, *slapping* and *drowning* audiences on 2D streaming platforms via the virtual camera, he can directly involve viewers in his embodied social VR activities through an immersive first-person perspective.

Strategy Limitation: Manipulating Camera in Social VR Creates Extra Workload for Streamers and Can Lead to Uncomfortable or Interrupted Viewing Experiences. Despite these novelties, our participants still express several concerns about manipulating camera in social VR that can negatively impact both *streamers'* and *viewers'* experiences.

For streamers, multiple participants report that camera glitches can occur occasionally during their streams. These issues include but not limited to: glitchy camera movements, frozen image, and corrupted image output. P1 describes, *"Sometimes moving camera causes weird things and it (the camera) would lag really far behind (my model)."* For P1, because the camera cannot follow his hand movements properly and in real time, it could lead to significant lags and fail to capture what he actually wants to show to his audiences. P12 adds another example: *"the camera can be completely frozen. So when it does happen, my viewers may think it is their own internet lags, because everything freezes."* In this case, P12's stream image completely froze because their camera stopped working. This incident not only paused P12's stream but also confused their audience. As such, P12 was forced to explain and ask their viewers to refresh their pages.

Beyond these technical complexities, creatively managing the virtual camera in social VR streaming can be time-consuming and demanding. Many streamers point out the severe issue of information overload when managing camera in social VR – "a wall of screens" shown in Figure 6. P7 summarizes,

"Social VR streams definitely require a lot more setup than other streams. I have to monitor many PC windows even if I am already in VR - my stream image, my chat window, my Twitch channel window for viewer redeems, a Discord window for texting, and so on. It is a lot more management."

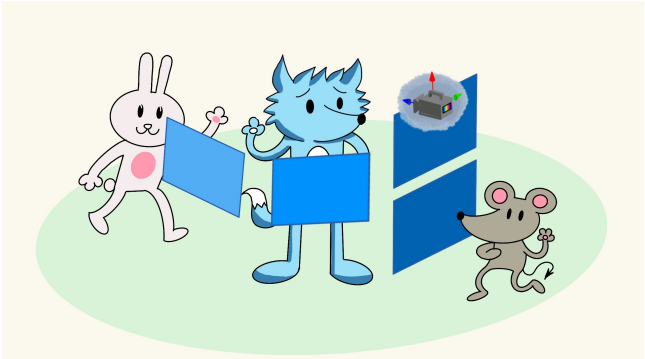

Figure 6: The issue of "a wall of screens" for social VR streamers. Although these virtual screens are not visible to other social VR users and their audiences outside VR, the streamer can be visually blocked and mentally overwhelmed by managing many screens simultaneously.

For streamers like P7, to better monitor and manage their camera, they have to keep several virtual windows within the social VR space to mirror their PC software. However, they not only need to pay attention to all these virtual windows simultaneously but also have to make sophisticated decisions within each of the windows. For example, in stream monitoring window, social VR streamers need to check both the original camera image (e.g., camera angle, image content, and lighting) and other overlaid elements like chat box, heart rate display, and channel information including audience statistics. Worse still, sometimes these windows can physically

block streamers' views, making it even harder for them to stay in touch with other social VR users while attending to their viewers (e.g., *"I could only see around the edges to see other players come up to me and try to get my attention, but I would be busy watching these windows."* -P3). P15 further highlights how separating these windows still cannot address this problem but introduces new challenges, *"I usually separate my windows such that they don't cluster together and completely block my view. However, this causes my camera and chat not in the same place. [...] So when I am reading the chat, I am not looking at the camera."* P15 has to physically turn their body back and forth to view different windows. This thus significantly delays their reactions to audiences and makes them physically and emotionally exhausted from managing too many windows from different angles all at once.

Regarding viewers, streamers' creative camera control may cause uncomfortable or interrupted watching experiences, rather than engaging them. P11 especially notes the motion sickness issue,

"I must avoid to set my camera when I am moving. For example, my audiences can feel very uncomfortable if I just dance while also grabbing my camera."

As previously described, social VR streamers often need to directly grab or drag the third personcamera (i.e., viewers watch what the streamer is doing from a third person perspective) to interact with their audiences. However, if the streamer is managing the camera when conducting intensive physical activities (dancing in P11's case), the captured image can be tremulous and thus make the viewers feel physically uncomfortable. If the streamer is using the first person camera (i.e., viewers see what the streamer is seeing through the streamer's eyes), this issue may become more severe because such a camera always aligns with streamers' head-tracked movement. As such, the image captured by the first-person camera could be completely jittery, making audiences experience even worse motion sickness when watching.

P12 echoes this sentiment by adding another fundamental issue about using the first person camera: *"the way your VR headset works is that you are displaying two separate screens, [...] if you are streaming through your right eye, viewers might not even see the things you can see in your left eye."* Therefore, when streaming with the first-person camera, audiences may only see part of the streamer's full field of view. In some cases, streamers may refer to certain objects or activities that their audiences cannot see, which significantly jeopardizes these streamers' efforts to fully convey their immersive social VR experience to viewers outside VR.

4.3 Strategy 3: Leveraging Tangible Interactions to Allow Audiences outside VR to Physically Shape Streamers' Embodied Experiences in VR

Our participants additionally leverage various interaction tools beyond traditional text-based chat to allow their audiences outside VR to trigger **sound, visual effects,** and **physical objects.** In doing so, viewers are able to directly influence and shape streamers' embodied experiences in social VR in tangible ways.

First, streamers incorporate various **sound redeems** (a feature on streaming platforms that allows viewers to trigger sound effects by spending virtual points) that they can hear in social VR (Figure 7). P8 and P10 describe,

"My viewers can play sounds like applause or congratulations. Usually, when I say something that really, really moves them, they tend to play those just to say like, 'Wow, thank you,' or 'That really helped.' (P8)

"I get scared very easily. When I am immersed in a horror-themed VR world, my audiences use such redeems to make me shriek and squeak or run away. They are like naughty friends standing behind me." (P10)

To both participants, sound redeems allow them to directly hear from their audiences instead of reading text from them, making their viewers' presence and participation in their VR streams more evident (*"like naughty friends standing behind me"*). Such sounds effects also further foreground the significant role of viewers in shaping the streamer's VR activities, such as by making P10 *"shriek and squeak or run away."*

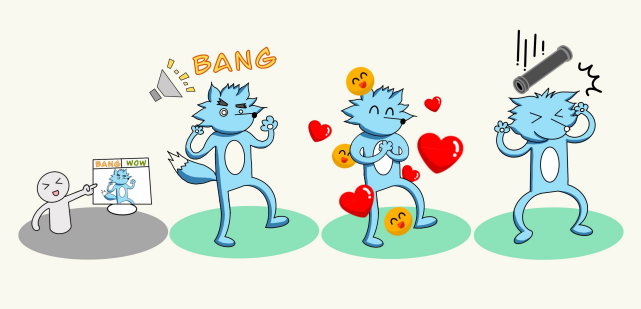

Figure 7: Examples of tangible audience interactions in social VR streaming. From left to right: (1) sound redeems, (2) visual elements redeems, and (3) physical objects redeems.

Second, some interaction tools allow viewers outside VR to create or modify **visual elements** on streamers' virtual avatars or in their VR environments. For example, P14's audiences can spawn emoticons around her VR avatar and thus express themselves in a more visible way (Figure 7):

"My viewers can spawn as many emoticons as they want. Sometimes their 'likes' and 'hearts' can get so many and literally flood me. So I would be like, 'okay I know you love me so much, please stop', which can be hilarious."

For streamers like P14, visual effects like emoticons allow their audiences outside VR to be visually co-present with their VR avatars, leading to a unique sense of social gathering in the VR space. P15 thus compares her social VR streaming to offline *"on-the-stage"* or *"in-the-street"* performances due to this constant sense of social gathering with her audiences in the VR space, further strengthening the emotional bonds between her and her viewers.

Third, some participants have also programmed their avatars to allow viewers to spawn **physical objects** in VR space that can interact with the streamer's virtual body. For example, P16's model allows his audiences to "hit" him in social VR during his stream (Figure 7):

"When my viewers trigger a certain gift, a steel tube will drop on my head, making a very loud sound. I will cover my head with my hands and say 'ouch.'"

Here, P16's viewers not only transcend the boundary between the VR and non-VR worlds to physically affect the streamer's body (e.g., *"a steel tube will drop on my head"*) but also directly see the outcome of such impacts in the real time (*"making a very loud sound," "ouch"*). Some streamers go even further to materialize their interactions with their viewers, such as through a *"tangible chat system"* (Figure 8) or haptic vests,

"The map can process my chat into 3D models in real time. [...] Whenever they say something good and interesting, I can turn around, grab that specific chat and stick it onto my 'wall of fame', and whenever they say something naughty, I can use that chat as a towel and then throw it into a trash bin." (P17)

"When my audience trigger that gift, it not only creates a 'hug' emoticon, but can trigger a vibration on my haptic vest, like I am being hugged in real world." (P15)

Both participants use even more novel methods to physically interact with their viewers outside VR. P17 created his own *"tangible chat system"* in a self-made social VR map, which materializes audiences' chats into 3D text models floating behind his model. In doing so, he is able to create dramatic performances that physically involve audience messages, as if he was standing, speaking, and performing on a physical stage. P15 often wears haptic vests during her streams. This allows her audience to actually "touch"and "hug" her. In both ways, these streamers' engagement with their viewers goes far beyond just on-screen text chat but actually simulates face-to-face, physical interactions.

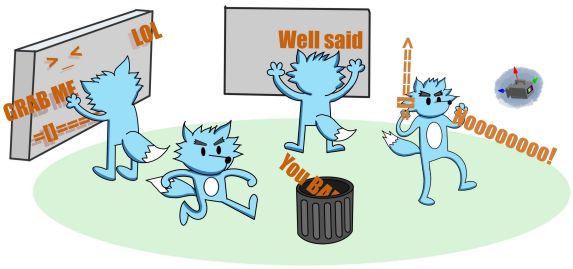

Figure 8: An example of the "tangible chat" system used in social VR streaming. From left to right: in social VR, a streamer can (1) grab an audience message from the live chat generator, (2) throw a "bad" chat into a trash bin, (3) post a "good" chat on the wall, and (4) creatively perform using tangible chat objects generated by audiences.

Strategy Limitation: Excessive Tangible Interactions Can Lead to Chaotic and Distracting Experiences for Streamers, Audiences, and Even Other Social VR Users. Yet, streamers also acknowledge that excessive tangible interactions can lead to chaotic and distracting experiences to streamers themselves, their viewers, and even other users in social VR. Above all, it is challenging for **streamers themselves** to focus on their planned activities in social VR when excessive sound, visual effects, and physical objects redeems generated by their viewers are happening around them. P14 and P16 share their frustration,

"When viewers throw objects to my body, the model will make an 'ouch' face, no matter if I am in the middle of smiling or crying. [...] Also, my model will fall to the ground if it gets too many hits within a certain period of time, like becoming a 'rag doll'." (P14)

"One day, a viewer paid for 1000 sound redeems and my stream get completely doomed. Basically I couldn't speak for like 15 minutes." (P16)

In P14's case, too many tangible interactions from her viewers (e.g., *"hits"*) can overwrite her ongoing body-tracking and face-tracking. For P16, even just one viewer can overuse the redeem system and take over his whole stream for a period of time. Therefore, social VR streamers often have to balance the significant benefits of creative tangible interactions for engaging with their viewers and the urgent need for setting up a delicate limit of the appropriate amount of tangible interactions allowed in their stream. Otherwise their live streaming might be physically distracted or even forced to stop.

Likewise, it is equally challenging for **viewers** to fully engage in the ongoing social VR stream if other viewers are making surprising sounds or excessive tangible interactions at the same time. P13 and P14 share their experiences,

"Usually when I tell a joke, people laugh after you finish it. So if someone just laugh in the middle, it actually makes the joke less funny." (P13)

"I was really hoping to show that moment, but it was just so unlucky that the flooding 'heart' emoticon completely covered my body. [...] Even though it was by a good intention, it actually hurt my stream, because you just cannot make it up when the climax moments was gone." (P14)

For these participants, audiences' sound redeems can spoil the emotional build-up or block the key moment of their streams, deflating the engagement of all other viewers. As a result, these tangible interactions can create overwhelming distractions that prevent viewers from paying attention to the streamer and the stream *per se*, rather than helping the streamer engage with their viewers.

These excessive tangible interactions may even negatively affect **other social VR users**. Most participants do not make their sound redeems audible to other users in the social VR space with them, who may or may not be aware of their streaming practices. However, the visual and tangible objects are usually visible to anyone around the streamers in the VR space. Therefore, when streamers' audiences trigger too many visual or tangible effects, other social VR users can also be visually disturbed, for example:

"I felt it getting out of control too often, and others can barely see me because I would be fully in fire." (P11)

"When there are too many chats floating behind, it becomes especially lag if you still keep them visible to everyone else in VR." (P17)

Here, we see how P11 was unable to engage with other social VR users surrounding him because his viewers triggered too much *"fire"* effect on his avatar. As such, he could not maintain a stable and visible virtual appearance that was essential for other social VR users to recognize and interact with him. P17 further points out when excessive redeems happen, everyone in the social VR map could experience image lag, and some of them even face system crash or shutdown. Therefore, while these tangible effects provide unprecedented opportunities to connect streamers with their viewers in a more physical way, they pose extra burden upon the entire social VR ecosystem if not managed appropriately.

4.4 Strategy 4: Collaboratively Roleplaying Streamers' VR Avatars to Foster More Personalized Connections with Their Audiences outside VR

Lastly, social VR streamers highlight collaboratively *roleplaying* their VR avatars with their viewers as another key strategy to foster more personalized connections with their audiences outside VR. Indeed, due to the "social" nature of social VR, streamers are usually not alone in these VR spaces when they are streaming. Therefore, instead of talking in their everyday tone, streamers may **intentionally join or create roleplay conversations to interact with other social VR users** in fictional "roles" for viewers to watch and comment on. P17 explains,

"It would be boring to watch if you keep talking in a daily 'how are you' style. [...] We usually do shouting out sale events in VR. So other players [in social VR] will play as the shop assistants, and we sale everything around us [in VR environment] to viewers. [...] The funny part is that, because my model is a special one, and I can take my body part off, so sometimes I sell my head to my viewers."

In this example, P17 "roleplayed" a shopkeeper in his stream with other social VR users *"as the shop assistants."* In doing so, he went beyond just *"a daily 'how are you' style"* but created unique, entertaining moments for his viewers to watch, such as selling his own head. This strategy thus makes his stream content more dramatic and appealing, which bridges the in-VR activities with outside VR audience engagement in more context-specific and memorable ways (e.g.. viewers can bid on P17's head through tangible chat).

P2 shares a similar example,

"If I am in the hotel reception desk, people will walk over as hotel guests and try to make funny moments, like they want to bring an alligator, who is also a VR player. [...] I would wait a bit for my viewers, because they sometimes do funny replies. So in this example, they said things like, 'first of all, which one of you is the pet?'"

By playing a hotel receptionist who frequently interacts with other social VR users as hotel guests, P2 effectively encourages her viewers outside VR to also actively engage in this roleplay in VR. As highlighted in P2's account, her audiences would not only just watch her roleplay but also give her suggestions about how to respond to other social VR users in this "play," as if they were facing the same problem solving scenario.

Additionally, some streamers allow their **viewers to directly control their VR avatars or even interact with other social VR users through their avatars** as part of the streamer-audience co-play. P9, for instance, created an avatar with a secondary "spirit" entity floating around her head. She also set up a system allowing her Twitch chat to control the spirit's actions and emotions through commands:

"Every so often they'll let me know, 'Hey, we'd like to be able to express this emotion or this expression. Do you think you could add one?' I'll try my best to add it as quickly as I can. [...] I think the viewers are participating in building the characters, because it makes the character more complete in some sense. [...] Other people in social VR are aware of this spirit and will talk to them. [...] They can also see my viewers' mood, like 'who is so happy?'"

In P9's case, she let her viewers to co-design avatars and models that can best convey viewers' own *"emotion"* and *"expression."* In doing so, her audiences not only co-present with her in the VR space but also co-roleplay to directly interact with other users in VR through her avatar body. As a result, her viewers are not merely audiences but can build intimate and personalized connections with her to make the VR streaming experience *"more complete."*

Taken together, although roleplay typically involves imaginary roles and scenarios in social VR, it allows social VR streamers' viewers to know them *"on a more realistic level"*:

"Whenever I'm doing normal activities, people are just watching me doing normal reactions and funny jokes. But whenever I do VR roleplay in fantasy worlds, I feel like my audience gets to know me on a more realistic level. [...] They enjoy watching me get scared, because they see my real reactions. I think it's a way for them to be closer to me, to 'hang out,' than it would be to be like if I was just playing a video game alone [...] I feel like it's a value to them, because they can see [...] a little more authentically me." (P7)

For participants like P7, roleplaying in social VR seems to help them showcase how they would typically interact with other social VR users in various social scenarios to their viewers (*"they see my real reactions"*). These streamers believe that roleplaying can provide their viewers with nuanced opportunities to gain more in-depth understandings of their personalities and behavioral patterns (e.g., *"a little more authentically me"*) , which their viewers would not have had access to in other contexts (e.g., when the streamer *"was just playing a video game alone"*).

Strategy Limitation: Challenges to Simultaneously Manage Interactions with Both Viewers and Other Social VR Users and Risks of Unwanted Encounters. However, participants also collectively share their concerns about how collaborative roleplay may create new difficulties for them to manage interactions with both viewers and other social VR users all at the same time. Several participants explain,

"When I'm roleplaying, I can't really interact with my chat that much because I'm in a role and obviously should have conversation with other roles. I can't take breaks, like muting my VR voice and talking to the chat, because it would not align with my role in that play." (P2)

"So obviously other people cannot see my viewers when I talk to them, except you have some super advanced model or map. It is also true that my viewers cannot see some out-of-screen players when I am talking to them. So this makes my stream a bit difficult, because there are too many one-sided mirrors." (P16)

For P2, her roleplay requires her to fully immerse in her role, meaning that she has to focus on interacting with other social VR users by playing this role. As such, to deliver a believable "roleplay" performance, P2 would not be able to interact with her viewers outside VR without breaking the flow of her roleplay performance. P16's account further points out that social VR streamers often have to attend to both other users in social VR and audiences outside VR. Therefore, they have to frequently switch between multiple ongoing conversations with both people in and out of VR. This can become a quite confusing experience for everyone: other social VR users may see P16 strangely "talking to the air," while his viewers outside VR may not understand what P16 is referring to, as the camera may not be able to capture multiple social VR users interacting with the streamer at once.

Streamers are also worried about their personal safety because collaborative roleplay may increase their risks of encountering strangers in social VR, leading to potentially negative or harmful experiences. P4 and P16 both warn,

"In public room or roleplay, there may still be some harassment stuff come your way... You can block them out using the provide the tools within VRChat, but it still becomes one of the reasons that many streamers just don't play with any strangers." (P4)

"No matter who is speaking, my hand is always on the 'mute' button. You generally don't know who is gonna say something that can immediately turn your stream over. [...] It definitely divides my attention and can stress me very badly." (P16)

While streamers like P4 and P16 appreciate how they can build more intimate and personalized connections with their viewers through collaborative roleplay, they feel that it inevitably increases the chance for them to encounter potential harassers. Indeed, roleplay usually requires multiple social VR users to collectively "perform" their assigned roles. This means that the streamer cannot deliver a satisfactory roleplay experience for their viewers without involving other social VR users - online strangers who may or may not be harassers. As a result, to avoid possible harms from unknown online strangers, some streamers like P16 usually only roleplay with friends or have to avoid roleplay altogether.

5 Discussion

In answering our research questions, Table 2 summarizes our key findings. In this section, we first discuss how our findings transcend traditional streaming research in HCI by going beyond conventional 2D streamer-audience interactions, particularly through embodied and physicalized engagement strategies unique to VR settings and nuanced cross-reality interactions (**5.1**). In section **5.2**, we offer our critical reflections on multiple conflicts and dilemmas emerging in social VR streamers' endeavors. Grounded in these understandings, we then propose potential directions to inform the design of future social VR and streaming platforms to better support more complicated cross-reality social dynamics across VR and non-VR spaces while mitigating potential challenges and limitations.

5.1 Transcending Traditional 2D Streaming Through Embodied and Physicalized Engagement and Cross-Reality Interactions

Prior works have begun to explore how we can enhance more nuanced and immersive streamer-viewer interactions beyond just verbal or non-verbal communications on a 2D screen [11, 33, 34, 58, 71], such as through manifesting external objects (e.g., manipulating a streamer's room lighting) [34, 55]. Built upon these prior works, our study has highlighted social VR streaming as a new lens to transcend traditional 2D streaming experiences by facilitating direct physicalized and embodied engagement and cross-reality interactions between streamers and viewers. Indeed, **compared to traditional 2D live streaming**, our findings further emphasize the uniqueness of social VR in recreating more face-to-face social interactions between VR streamers and their non-VR audiences, making it feel like they were physically interacting with each other in the offline world [17, 18, 43, 59, 66]. Additionally, **compared to existing research on cross-reality interactions** that mainly highlights the role of asymmetric collaborative setups and bystander engagement in bridging communication across various realities [27, 49, 51, 53, 54, 57, 65], our findings reveal how social VR streamers leverage even more creative and complex strategies (e.g., more physicalized and tangible interactions) to facilitate more intuitive streamer-audience interaction across different realities (e.g., VR and non-VR).

Specifically, we unpack three new mechanisms demonstrated in social VR streaming, which offer novel insights into expanding existing literature on both cross-reality interactions and integrating VR and 2D audience experiences. These mechanisms include: (1) building a sense of physical co-presence with viewers through embodiment and free style camera work; (2) planing and enabling viewers' tangible involvement in VR to facilitate more physicalized cross-reality interactions; and (3) expressing a more genuine self by leveraging social VR's uniqueness to engage audiences more effectively than in traditional 2D streaming contexts.

(1) Building a sense of physical co-presence with viewers through embodiment and free style camera work. First, our study highlights how social VR streamers creatively solve the physical divide between streamers and viewers in traditional 2D streaming by acting as *a more embodied actor* and *a free style cameraman* to create a sense of physical co-presence with their viewers. Compared to traditional 2D streaming (e.g., through a desktop PC), social VR streamers can place all displays in the VR space surrounding their virtual body. Along with active full-body and facial tracking in real time, they can then freely move around and use their body languages and facial expressions to both perform nuanced activities in social VR and interact with their audiences outside VR in a more natural and realistic way [17, 18, 43, 59, 66]. Therefore, they become a *"more animated"* and embodied *actor* than in traditional streaming. This helps them further elevate additional non-verbal social cues to make their viewers feel that they were interacting with the streamer in a way alike face-to-face communications.

Additionally, in traditional 2D streaming, the physical web camera is usually placed or wired in a fixed position (e.g., on the top of the desktop). As such, streamers' control over the camera is usually limited to only manipulating the camera image (e.g., the relative size of the image) rather than the camera itself [29]. In contrast, streamers in social VR can freely move and physically interact with their virtual camera at any positions, making them a *free-style cameraman*. This practice enables close-up views on streamers' verbal and non-verbal expressions (e.g., bringing the camera to their faces). It also turns the streaming camera from a static and fixed device into a dynamic and cinematic first person viewpoint. In doing so, viewers outside VR can immersively engage in the streamer's activities in VR (e.g., sitting beside the streamer) or experience the streamer's reactions to audience in a realistic way (e.g., being slapped or drowned by the streamer). Taken together, compared to traditional streaming, this combination thus fosters a sense of physical co-presence by simulating how audiences in 2D, non-VR spaces (i.e., live streaming platforms on the screen) can (a) see what the streamer is seeing within 3D immersive VR spaces in real time and (b) directly interact with the streamer as if they were in the same physical space.

(2) Planning and enabling viewers' tangible involvement in VR to facilitate more physicalized cross-reality interactions. Another insight from our study is that compared to traditional 2D live streaming, social VR streamers make extra efforts to plan and enable their non-VR viewers' tangible impacts and agency that shape both streamers' personal (e.g., how they explore and experience social VR by themselves) and social (e.g., how they interact with other people in social VR) experiences in VR, leading to more physicalized cross-reality outcomes. Existing research on live streaming has pointed out that the sense of *"being seen"* or *"being heard"* by streamers [11, 58] and other audiences [33, 42, 81] is crucial for viewers to both confirming the streamer's attention to them and sustaining their own continuous engagement in the stream. Our study reveals that social VR streamers significantly elevate this concept by innovating how their viewers can be *seen* and *heard* in more physical ways beyond the visuals on the screen, such as through transforming visual elements on 2D screens (e.g., emoticons and polls) into 3D tangible objects in VR (e.g., 3D emoticons). Such tangible impacts are visible to not only all viewers outside VR but also other users in social VR, which not only facilitates physicalized cross-reality interactions between VR streamers and non-VR viewers but also further heightens viewers' sense of social engagement and participation in the VR space.

Indeed, social VR streamers tend to invite their viewers to physically influence their VR activities (e.g., interacting with other social VR users through the streamer's avatar) and their virtual body (e.g., co-designing the streamer's avatar with the streamer or hit the streamer's avatar with a steel cube) by combining 3D effects with tangible outcomes. They also go even further to magnify the physical outcome of these cross-reality interactions on their VR experiences (e.g., shouting "ouch" and grabbing audiences' chat as a physical object). This additional layer thus strengthens viewers' sense that they can participate in cross-reality interactions and impact the streamer in a different reality (e.g., in VR) not only verbally or non-verbally but also physically and socially.

Taken together, while social VR streaming shares certain characteristics with previous cross-reality research, such as asymmetric displays and interaction tools for effective cross-reality communication [27, 49, 54, 57, 65] and bystanders' participation in cross-reality interactions [1], it further emphasizes the intuitive and tangible outcomes of such cross-reality interactions, which facilitates a more natural and engaging experience for both streamers in VR and viewers on 2D streaming platforms. In this sense, social VR streaming seems to demonstrate more nuanced and complicated cross-reality social dynamics than those previously studied task-oriented settings in existing literature on cross-reality interactions [27, 49, 54, 57, 65].

(3) Expressing a more genuine self by leveraging social VR's uniqueness to engage audiences more effectively than in traditional 2D streaming contexts. Previous research on traditional live streaming has highlighted how streamers can craft their online identities either through selective performance based on Goffman's metaphor of *theatrical performance* [25] (e.g., Virtual YouTubers adhering to character personas [14, 41, 64]) or authentic self-presentation (e.g., webcam-based streamers emphasizing their offline identities [20]). However, our study adds new insights into how social VR's unique focus on embodied self-presentation and immersive roleplay experiences introduces nuanced possibilities for streamers to express a more genuine self to engage audiences more effectively than in traditional 2D streaming contexts.

First, as social VR users often feel higher ownership or identification with their virtual bodies and selves [3, 16, 18, 19, 22, 37, 68, 76, 78, 79], social VR streamers are motivated to demonstrate a more realistic image of themselves to their viewers. This practice thus significantly differs from both Virtual YouTuber streamers' intention to selectively present themselves imposed by pre-programmed virtual avatars [14, 64] and certain webcam-based streamers' (e.g., LGBTQ or women streamers) struggles with manipulating webcams and microphones to authentically present themselves [20]. As our findings show, social VR streamers often compare their VR streaming experiences to offline "*on-the-stage*" or "*in-the-street*" scenarios. Therefore, unlike traditional 2D streaming where webcams or programmed 2D avatars significantly frame or even limit the streamers' freedom and scope of performances, social VR provides streamers with a much more open virtual stage to move their virtual bodies and express themselves freely.

Second, social VR enables more context-rich, immersive interactions beyond typical 2D streamer-audience dynamics. In social VR, streamers can freely engage in uniquely simulated, "roleplay" activities with other social VR users to craft more immersive content for their viewers to watch. While they are performing fictional "roles," their key strategy to engage with viewers is to still intricately express their offline personalities and behavioral patterns to provide viewers with *"real"* and *"more authentic"* reactions through their embodied interactions with other social VR users. Such roleplay offers viewers a more comprehensive image about how a streamer would behave and interact with others in mundane, daily social scenarios. It also allows social VR streamers to particularly highlight key aspects of their personalities (e.g., problem solving skills or being humorous and easy-going) to their viewers through creative activities.

In summary, through social VR's unique support for steamers' embodied self-presentation and immersive roleplay experiences, social VR streaming seems to further break down the usual barrier between "front-stage" (public presentations) and "back-stage" (private, authentic selves) [24] in traditional live streaming due to 2D technical constraints (e.g., limitations of a 2D flat screen). In social VR streaming, each roleplay scenario and spontaneous reaction allows audiences to glimpse a rich portrait of the streamer's authentic self in a more immersive and realistic way. This natural accumulation of genuine interactive moments thus continues to foster deeper and more personal bonds between streamers and audiences compared to traditional 2D streaming.

5.2 Designing for Supporting Social VR Streamers' Endeavors to Transcend Traditional Live Streaming While Mitigating Emerging Conflicts and Dilemmas

Despite these nuances, our findings have also identified several critical limitations in social VR streamers' innovative endeavors to bridge immersive VR experiences with viewers outside VR, which may cause disruptive experiences for not only streamers and viewers but also other social VR users. Indeed, a small body of existing research has acknowledged VR streamers' multi-faceted challenges

to both engage in VR spaces and interact with viewers on non-VR platforms (e.g., Twitch) by studying recorded videos of VR streaming as second hand evidence [74]. Based on social VR streamers' first-hand experiences, we further expand these understandings by critically reflecting upon emerging conflicts and dilemmas social VR streamers are facing, particularly around difficulties to balance between VR's immersive experiences and excessive personal burden for streaming (**Reflection 1**), ethical and safety concerns surrounding tracking technologies in social VR streaming (**Reflection 2**), and technical limitations of real-time cross-reality interaction management across VR and non-VR platforms (**Reflection 3**). For each reflection, we also propose several high-level principles aimed at facilitating social VR streamers' endeavors to transcend traditional live streaming while mitigating these potential conflicts and dilemmas.

5.2.1 Reflection 1: Designing for Mitigating Difficulties to Balance Between Streamers' Endeavors to Deliver Immersive Body Performance in VR and Their Excessive Personal Burden. In our study, all of our participants acknowledge the inherent conflict between their creative strategies to deliver immersive body performance and the excessive personal burden they have to suffer as a result. Indeed, to fully engage their audiences outside VR, social VR streamers must smoothly leverage and switch between multiple advanced technical features and tools (e.g., camera control, body tracking, multiple virtual displays, and managing tangible interactions). As these techniques typically require manual control through hand-tracked VR manipulation (e.g., grabbing cameras and dragging tangible chat elements), learning how to use and better manage these systems in real time (e.g., during an ongoing stream) can lead to excessive personal burden on the streamer, including considerable physical and mental challenges. Worse still, these systems are also often unstable (e.g., lost tracking and lagging camera), causing additional pressure in streamers' already stressful situation.

Therefore, to ease streamers' personal burden in delivering immersive body performance in VR, we propose two design directions. First, while social VR streamers have leveraged multiple advanced technical features and tools, manually manipulating the virtual camera seems to require most of their attention and labor during streams. Therefore, we advocate for **improving the VR camera system with easier control that does not require excessive manual manipulation.** For example, adding more built-in camera features can make advanced cinematographic effects (e.g., montage effect by quickly switching camera positions) more accessible to streamers, rather than requiring them to manually build such effects on multiple displays during their stream. It is equally important to provide streamers with more one-click handles to these solutions. In doing so, streamers can be more flexible and efficient in camera controls in real time, which would facilitate a better flow in their ongoing performances in VR.

Second, we recommend **implementing several robust error mitigation mechanisms to help social VR streamers maintain the continuity of their stream even when technical issues arise.** For example, when tracking glitches happen, an automatic avatar control mechanism can be triggered to help the streamer maintain a stable presence in social VR until their tracking system is restored. Meanwhile, an automatic notification mechanism can be activated to alert the streamer of the technical issues without disrupting the viewer experience. This timely awareness of sudden technical issues during live streaming can prevent the social VR streamer from overlooking glitches and causing more confusions among their viewers. Lastly, it would also be valuable to implement a quick "reset" solution to help social VR streamers immediately refresh their multiple streaming settings when such technical issues happen. This one-click solution would not only minimize potential "downtime" during social VR streams but also relieve the streamer from significant personal labor and stress of trying to restart their individual systems to fix technical issues.

5.2.2 Reflection 2: Designing for Mitigating Ethical and Safety Concerns Surrounding Tracking Technologies in Social VR Streaming. Our study also highlights another important dilemma embedded in social VR streamers' strategies: to fully engage their viewers outside VR, streamers often need to compromise their own online safety to a certain degree. First, as shown in our findings, social VR streamers' privacy can potentially be infringed by full-body and facial tracking systems (e.g., capturing and broadcasting streamers' intimate personal activities such as going to the bathroom). In addition to these immediate privacy risks, VR tracking technologies may also lead to long-term privacy issues. For example, recent research has shown that body tracking data in VR can be used as distinctive biometric identifiers to identify individuals in the offline world, leading to more severe privacy breaches beyond merely streaming moments in VR [50]. This thus further demonstrates more heightened tensions between immersion and privacy in social VR streaming compared to traditional streaming. While traditional live streamers face similar tensions between authentic, appealing self-presentation and protecting identifiable personal information (e.g., physical features, appearance, and voice) [39, 75], they have access to various coping strategies such as applying camera filters, managing visual elements, and pausing streams when needed [75]. In contrast, social VR streamers face more complicated privacy risks due to the compulsive nature of VR equipment (e.g., headset and trackers bonded to physical body) and the lack of easy privacy controls in VR environments (e.g., no easy on/off option for body-tracking). This makes traditional privacy management strategies for streamers less effective or even impossible in social VR streaming contexts. Second, while social VR already presents more intense forms of harassment than traditional online communities because of its embodied and immersive nature [59, 60, 80], streamers may become even more vulnerable as they need to regularly interact with a larger number of online strangers in social VR (e.g., doing roleplays for viewers to watch). Their public-facing identities due to their streaming practices can inherently make them even more obvious targets for intended harassment, which leads to profound ethical concerns about how to better protect streamers to avoid potential exploitation of them in the social VR streaming context.

To mitigate these ethical and safety concerns surrounding tracking technologies while still allowing streamers to stream rich social activities in social VR, we first recommend **implementing more granular options for flexible tracking.** This would allow streamers to clearly configure personal boundaries between public, streamable and private personal activities during their streams, which could include new features to temporarily disable leg or

hand tracking without taking off the tracking devices. In addition, to avoid leaking identifiable personal information and causing long-term privacy issues, the tracking system can include obfuscation features to limit the fidelity of body movements being tracked and broadcasted while preserving essential motions for streaming. For example, social VR streamers should be able to customize the leg or arm motion ranges on their virtual avatars to prevent revealing their offline identity through overly precise body or facial tracking.

We then advocate for **designing more streamer-oriented safety tools in social VR to better protect streamers with high visibility to public.** Indeed, prior works on harassment in social VR have explored both platform specific safety tools (e.g., muting, blocking, and personal space bubbles) [4, 5, 21, 59] and personal strategies (e.g., avoiding head-on confrontation) [59] to mitigate growing harassment risks in social VR. While social VR streamers still can leverage these existing safety features to protect themselves, their unique public-facing roles require more nuanced protections due to various ethical concerns compared to normal social VR users. For example, they need to protect themselves from potential harassers in social VR without limiting their capability to engage with diverse social VR users to create novel content. Therefore, a potential new safety feature for streamers would be the ability to set up a protective "streaming zone" in social VR. In such a "zone," streamers will be able to quickly configure and grant various permissions to other social VR users who wish to participate in the stream and be heard and seen by viewers. We also emphasize that setting up such a "streaming zone" should not interfere with other social VR users' own experiences. For example, other social VR users should also be able to choose whether they want to see and interact with the streaming content in the zone and then accept or decline the streamer's invitation to participate. Additionally, once other social VR users begin participating in the stream, it is equally important for streamers to ensure that the streaming content remains safe for their viewers to watch. In this sense, a promising approach can be leveraging multi-camera system that can swiftly switch viewpoints to dis-focus on sudden and unexpected incidents. As such, streamers would be able to immediately withdraw themselves and their viewers from seeing any ongoing uncomfortable situations in their streams.

5.2.3 Reflection 3: Designing for Mitigating Technical Limitations of Real-Time Cross-Reality Interaction Management across VR and Non-VR Platforms. Lastly, our study highlights a fundamental paradox social VR streamers are struggling with - the dual role as both a regular user in social VR and a streamer. Indeed, in social VR streaming, the streamer is essentially a user in the social VR space. This means that they will need to interact with other users in VR to be part of the social VR community. However, they are also streamers who need to pay attention to their viewers outside VR to be part of the streaming community. This dual role (i.e., part of both the VR community and the streaming community) often leads to technical limitations of real-time cross-reality interaction management across VR and non-VR platforms. As a result, streamers either have to ignore viewers while engaging with other social VR users, or appear to "talk to the air" while interacting with other users.

Therefore, to help mitigate these technical limitations, we recommend **facilitating more cohesive interactions between streamers, other social VR users, and viewers outside VR through cross-reality, hybrid collaborations.** Prior works have specifically highlighted how asymmetric collaboration between users in different realities requires specialized tools and careful consideration of each reality's context in each step of their works [27, 49, 57, 65]. However, in social VR streaming, this asymmetry is further complicated as streamers need to maintain continuous interactions in and out of VR for smooth watching experiences. To address this, social VR platforms should establish interaction paradigms that seamlessly incorporate non-VR data into the virtual space. For instance, viewers' interactions from traditional live streaming platforms (e.g., Twitch chat flowers) can be automatically translated into interactive 3D objects (e.g., holdable VR bouquets) that both streamers and other VR users can naturally engage with. This system can be further refined through customizable controls that allow streamers to manage these interactions effectively, such as setting temporal limits (e.g., 10 bouquets per 30 minutes) and controlling visibility to specific users. In this sense, all parties in social VR streaming can maintain easier awareness of each other instead of requiring streamers' continuous efforts (e.g., regularly bringing up the chat window and read chat to other social VR users). As social VR users can see and interact with viewers outside VR, and viewers can witness how their participation is demonstrated in the VR space physically, social VR streaming can foster a more seamless sense of co-presence across realities and enhances the overall streaming experience for all participants in and outside VR.

5.3 Limitations

Our study has several limitations. First, although our participants represent a highly diverse sample of social VR streamers regarding ethnicity, gender, and sexuality, they mainly focused on one popular social VR platform (e.g., VRChat) and mainstream streaming services (e.g., Twitch, YouTube, and Bilibili in China). It is important for our future work to recruit participants who use other social VR and streaming platforms to paint a more comprehensive image of social VR streamers' additional strategies and challenges in bridging VR and non-VR experiences. Second, although 17 participants for a qualitative study focused on a unique population (i.e., social VR streamers) can be considered healthy and exceeds the typical interview sample size for CHI of 12 [8], most of our participants stream for small to medium sized channels (1,000 to 50,000 followers) and show variations of social VR streaming experiences from 3 months to 5 years. Future work may benefit from including a larger sample of streamers with more diverse levels of popularity and experiences and those working across different contexts (e.g., performance art, educational content, and cross-platform streaming). This would mitigate potential biases in participant responses stemming from this specific sample and help us better understand what strategies and nuanced practices might contribute to these streamers' various degrees of success in bridging VR and non-VR experiences. Third, by directly interviewing streamers, our study provides valuable insights into how social VR streamers approach their streaming practices and perceive the impacts on their viewers. However, future research could benefit from interviewing or

surveying viewers of social VR streaming to further verify these findings by understanding viewers' own perspectives.

6 Conclusion

Social VR platforms has dramatically transformed online social interactions by offering unprecedented embodied and immersive experiences. In this paper, we move beyond just understanding these interactions within social VR spaces but focus on how they can be extended beyond VR-only spaces to create novel cross-reality interactions blending both virtual and physical worlds, such as through social VR streaming. Our study has revealed how social VR streamers creatively leverage four key strategies to transcend traditional streamer-viewer interactions by bridging their immersive VR experience with their audiences on 2D streaming platforms outside VR. These strategies include *actively tracking full-body movements and facial expressions to naturally and intuitively engage with audiences outside VR*, *using novel camera control to directly immerse viewers outside VR in 3D VR experiences*, *leveraging tangible interactions to allow audiences outside VR to physically shape streamers' experiences in VR*, and *collaboratively roleplaying streamers' VR avatars to foster more personalized connections with their audiences outside VR*. We have also highlighted multiple conflicts and dilemmas emerging in social VR streamers' such endeavors and proposed design implications for future social VR and streaming platforms to better address these identified risks, including: (1) balancing between streamers' endeavors to deliver immersive body performance and their burden by specialized VR camera controls and tracking error recovery mechanics, (2) mitigating ethical and safety concerns surrounding tracking technologies by granular privacy controls and streaming boundaries in VR, and (3) mitigating technical limitations of real-time cross-reality interaction management across VR and non-VR platforms by unified interaction frameworks for easy cross-reality interactions. As online social spaces increasingly blend virtual and physical worlds, our work thus provides crucial insights into how these spaces can better support cross-reality engagement in more embodied and immersive ways, as shown in the case of social VR streaming, while still protecting user safety and privacy. These insights may inform future discussions around not only innovating traditional 2D streamer-viewer interactions but also developing more inclusive, engaging, and secure cross-reality environments.

Acknowledgments

We thank our participants and the anonymous reviewers. This work was partially supported by the National Science Foundation award # 2112878.

References

[1] Jonas Auda, Uwe Gruenefeld, Sarah Faltaous, Sven Mayer, and Stefan Schneegass. 2023. A Scoping Survey on Cross-reality Systems. *ACM Comput. Surv.* 56, 4, Article 83 (Oct. 2023), 38 pages. doi:10.1145/3616536

[2] Steven Baker, Ryan M Kelly, Jenny Waycott, Romina Carrasco, Thuong Hoang, Frances Batchelor, Elizabeth Ozanne, Briony Dow, Jeni Warburton, and Frank Vetere. 2019. Interrogating Social Virtual Reality as a Communication Medium for Older Adults. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (2019), 1–24.

[3] Steven Baker, Jenny Waycott, Romina Carrasco, Ryan M Kelly, Anthony John Jones, Jack Lilley, Briony Dow, Frances Batchelor, Thuong Hoang, and Frank Vetere. 2021. Avatar-Mediated Communication in Social VR: An In-depth Exploration of Older Adult Interaction in an Emerging Communication Platform. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–13.

[4] Lindsay Blackwell, Nicole Ellison, Natasha Elliott-Deflo, and Raz Schwartz. 2019. Harassment in Social Virtual Reality: Challenges for Platform Governance. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (2019), 100.

[5] Lindsay Blackwell, Nicole Ellison, Natasha Elliott-Deflo, and Raz Schwartz. 2019. Harassment in social VR: Implications for design. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, 854–855.

[6] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[7] Virginia Braun and Victoria Clarke. 2012. *Thematic analysis.* American Psychological Association.

[8] Kelly Caine. 2016. Local standards for sample size at CHI. In *Proceedings of the 2016 CHI conference on human factors in computing systems*. 981–992.

[9] Di Chen, Dustin Freeman, and Ravin Balakrishnan. 2019. Integrating Multimedia Tools to Enrich Interactions in Live Streaming for Language Learning. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–14.

[10] Yan Chen, Walter S Lasecki, and Tao Dong. 2021. Towards Supporting Programming Education at Scale via Live Streaming. *Proceedings of the ACM on Human-Computer Interaction* 4, CSCW3 (2021), 1–19.

[11] John Joon Young Chung, Hijung Valentina Shin, Haijun Xia, Li-yi Wei, and Rubaiat Habib Kazi. 2021. Beyond show of hands: Engaging viewers via expressive and scalable visual communication in live streaming. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–14.

[12] Elena Dzardanova, Vlasios Kasapakis, and Damianos Gavalas. 2018. *Social Virtual Reality.* Springer International Publishing, Cham, 1–3. doi:10.1007/978-3-319-08234-9_204-1

[13] Travis Faas, Lynn Dombrowski, Erin Brady, and Andrew Miller. 2019. Looking for group: Live streaming programming for small audiences. In *International Conference on Information*. Springer, 117–123.

[14] Júlio César Valente Ferreira, Rafael Dirques David Regis, Paula Gonçalves, Gabriela Rodrigues Diniz, and Vitor Pedro da Silva Castelo Tavares. 2024. VTuber concept review: The new frontier of virtual entertainment. In *Proceedings of the 24th Symposium on Virtual and Augmented Reality* (Natal, RN, Brazil) *(SVR '22)*. Association for Computing Machinery, New York, NY, USA, 83–96. doi:10.1145/3604479.3604523

[15] C Ailie Fraser, Joy O Kim, Alison Thornsberry, Scott Klemmer, and Mira Dontcheva. 2019. Sharing the studio: How creative livestreaming can inspire, educate, and engage. In *Proceedings of the 2019 on Creativity and Cognition*. 144–155.

[16] Guo Freeman and Dane Acena. 2022. " Acting Out" Queer Identity: The Embodied Visibility in Social Virtual Reality. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2 (2022), 1–32.

[17] Guo Freeman, Dane Acena, Nathan J McNeese, and Kelsea Schulenberg. 2022. Working Together Apart through Embodiment: Engaging in Everyday Collaborative Activities in Social Virtual Reality. *Proceedings of the ACM on Human-Computer Interaction* 6, GROUP (2022), 1–25.

[18] Guo Freeman and Divine Maloney. 2021. Body, avatar, and me: The presentation and perception of self in social virtual reality. *Proceedings of the ACM on Human-Computer Interaction* 4, CSCW3 (2021), 1–27.

[19] Guo Freeman, Divine Maloney, Dane Acena, and Catherine Barwulor. 2022. (Re) discovering the Physical Body Online: Strategies and Challenges to Approach Non-Cisgender Identity in Social Virtual Reality. In *CHI Conference on Human Factors in Computing Systems*. 1–15.

[20] Guo Freeman and Donghee Yvette Wohn. 2020. Streaming your identity: Navigating the presentation of gender and sexuality through live streaming. *Computer Supported Cooperative Work (CSCW)* 29 (2020), 795–825.

[21] Guo Freeman, Samaneh Zamanifard, Divine Maloney, and Dane Acena. 2022. Disturbing the Peace: Experiencing and Mitigating Emerging Harassment in Social Virtual Reality. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW1 (2022), 1–30.

[22] Guo Freeman, Samaneh Zamanifard, Divine Maloney, and Alexandra Adkins. 2020. My Body, My Avatar: How People Perceive Their Avatars in Social Virtual Reality. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–8.

[23] Giovanni. 2022. What do you need for virtual reality? https://www.coolblue.be/en/advice/what-do-i-need-for-virtual-reality.html

[24] Erving Goffman et al. 1978. *The presentation of self in everyday life.* Harmondsworth London.

[25] Erving Goffman et al. 1978. *The presentation of self in everyday life. 1959.* London: Harmondsworth.

[26] Kishonna L Gray. 2017. They're just too urban": Black gamers streaming on Twitch. *Digital sociologies* 1 (2017), 355–368.

[27] Jan Gugenheimer, Evgeny Stemasov, Julian Frommel, and Enrico Rukzio. 2017. ShareVR: Enabling Co-Located Experiences for Virtual Reality between HMD and Non-HMD Users. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*. ACM, 4021–4033. doi:10.1145/3025453.3025683

[28] Lassi Haaranen. 2017. Programming as a performance: Live-streaming and its implications for computer science education. In *Proceedings of the 2017 ACM Conference on Innovation and Technology in Computer Science Education*. 353–358.

[29] William A Hamilton, Oliver Garretson, and Andruid Kerne. 2014. Streaming on twitch: fostering participatory communities of play within live mixed media. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 1315–1324.

[30] Influencer Marketing Hub. 2020. 40 Useful Twitch Stats for Influencer Marketing Managers. *https://influencermarketinghub.com/twitch-stats/* (2020).

[31] Han Jin. 2022. How To Stream VR On Twitch 2023: Top Full Guide. https://lucidcam.com/how-to-stream-vr-on-twitch/

[32] Mark R Johnson and Jamie Woodcock. 2019. The impacts of live streaming and Twitch. tv on the video game industry. *Media, Culture & Society* 41, 5 (2019), 670–688.

[33] Yi-Chieh Lee, Chi-Hsien Yen, Dennis Wang, and Wai-Tat Fu. 2019. Understanding How Digital Gifting Influences Social Interaction on Live Streams. In *Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '19)*. ACM. doi:10.1145/3338286.3340144

[34] Pascal Lessel, Maximilian Altmeyer, Julian Sahner, and Antonio Krüger. 2022. Streamer's Hell-Investigating Audience Influence in Live-Streams Beyond the Game. *Proceedings of the ACM on Human-Computer Interaction* 6, CHI PLAY (2022), 1–27.

[35] Jie Li, Vinoba Vinayagamoorthy, Julie Williamson, David A Shamma, and Pablo Cesar. 2021. Social VR: A new medium for remote communication and collaboration. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–6.

[36] Lingyuan Li, Guo Freeman, and Nathan J McNeese. 2022. Channeling End-User Creativity: Leveraging Live Streaming for Distributed Collaboration in Indie Game Development. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2 (2022), 1–28.

[37] Lingyuan Li, Guo Freeman, Kelsea Schulenberg, and Dane Acena. 2023. " We Cried on Each Other's Shoulders": How LGBTQ+ Individuals Experience Social Support in Social Virtual Reality. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–16.

[38] Lingyuan Li, Jirassaya Uttarapong, Guo Freeman, and Donghee Yvette Wohn. 2020. Spontaneous, Yet Studious: Esports Commentators' Live Performance and Self-Presentation Practices. *Proceedings of the ACM on Human-Computer Interaction* 4, CSCW2 (2020), 1–25.

[39] Yao Li, Yubo Kou, Je Seok Lee, and Alfred Kobsa. 2018. Tell me before you stream me: Managing information disclosure in video game live streaming. *Proceedings of the ACM on Human-Computer Interaction* 2, CSCW (2018), 1–18.

[40] Zhicong Lu, Michelle Annett, Mingming Fan, and Daniel Wigdor. 2019. I feel it is my responsibility to stream: Streaming and Engaging with Intangible Cultural Heritage through Livestreaming. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, 229.

[41] Zhicong Lu, Chenxinran Shen, Jiannan Li, Hong Shen, and Daniel Wigdor. 2021. More Kawaii than a Real-Person Live Streamer: Understanding How the Otaku Community Engages with and Perceives Virtual YouTubers. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21)*. ACM. doi:10.1145/3411764.3445660

[42] Zhicong Lu, Haijun Xia, Seongkook Heo, and Daniel Wigdor. 2018. You watch, you give, and you engage: a study of live streaming practices in China. In *Proceedings of the 2018 CHI conference on human factors in computing systems*. 1–13.

[43] Divine Maloney and Guo Freeman. 2020. Falling asleep together: What makes activities in social virtual reality meaningful to users. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*. 510–521.

[44] Divine Maloney, Guo Freeman, and Donghee Yvette Wohn. 2020. "Talking without a Voice": Understanding Non-Verbal Communication in Social Virtual Reality. *Proc. ACM Hum.-Comput. Interact.* 4, CSCW2, Article 175 (Oct. 2020), 25 pages. doi:10.1145/3415246

[45] Joseph A Maxwell. 2010. Using numbers in qualitative research. *Qualitative inquiry* 16, 6 (2010), 475–482.

[46] Nora McDonald, Sarita Schoenebeck, and Andrea Forte. 2019. Reliability and inter-rater reliability in qualitative research: Norms and guidelines for CSCW and HCI practice. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (2019), 1–23.

[47] Joshua McVeigh-Schultz, Anya Kolesnichenko, and Katherine Isbister. 2019. Shaping Pro-Social Interaction in VR: An Emerging Design Framework. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–12.

[48] Sharan B Merriam and Elizabeth J Tisdell. 2015. *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

[49] Jens Müller, Johannes Zagermann, Jonathan Wieland, Ulrike Pfeil, and Harald Reiterer. 2019. A Qualitative Comparison Between Augmented and Virtual Reality Collaboration with Handheld Devices. In *Proceedings of Mensch Und Computer 2019* (Hamburg, Germany) *(MuC '19)*. Association for Computing Machinery, New York, NY, USA, 399–410. doi:10.1145/3340764.3340773

[50] Vivek C Nair, Gonzalo Munilla-Garrido, and Dawn Song. 2023. Going Incognito in the Metaverse: Achieving Theoretically Optimal Privacy-Usability Tradeoffs in VR. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology* (San Francisco, CA, USA) *(UIST '23)*. Association for Computing Machinery, New York, NY, USA, Article 61, 16 pages. doi:10.1145/3586183.3606754

[51] Ohan Oda, Carmine Elvezio, Mengu Sukan, Steven Feiner, and Barbara Tversky. 2015. Virtual Replicas for Remote Assistance in Virtual and Augmented Reality. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology* (Charlotte, NC, USA) *(UIST '15)*. Association for Computing Machinery, New York, NY, USA, 405–415. doi:10.1145/2807442.2807497

[52] Anthony J Pellicone and June Ahn. 2017. The Game of Performing Play: Understanding streaming as cultural production. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. 4863–4874.

[53] Krzysztof Pietroszek and Chao Cheng Lin. 2019. UniVResity: Face-to-Face Class Participation for Remote Students using Virtual Reality. In *Proceedings of the 25th ACM Symposium on Virtual Reality Software and Technology* (Parramatta, NSW, Australia) *(VRST '19)*. Association for Computing Machinery, New York, NY, USA, Article 97, 2 pages. doi:10.1145/3359996.3364730

[54] Ronald Poelman, Oytun Akman, Stephan Lukosch, and Pieter Jonker. 2012. As if being there: mediated reality for crime scene investigation. In *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work* (Seattle, Washington, USA) *(CSCW '12)*. Association for Computing Machinery, New York, NY, USA, 1267–1276. doi:10.1145/2145204.2145394

[55] Raquel Breejon Robinson, Ricardo Rheeder, Madison Klarkowski, and Regan L Mandryk. 2022. " Chat Has No Chill": A Novel Physiological Interaction For Engaging Live Streaming Audiences. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–18.

[56] Stream Scheme. 2021. How to VR Stream on Twitch. https://www.streamscheme.com/how-to-vr-stream-on-twitch/

[57] Jan-Henrik Schröder, Daniel Schacht, Niklas Peper, Anita Marie Hamurculu, and Hans-Christian Jetter. 2023. Collaborating Across Realities: Analytical Lenses for Understanding Dyadic Collaboration in Transitional Interfaces. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 97, 16 pages. doi:10.1145/3544548.3580879

[58] Patrick Schuck, Maximilian Altmeyer, Antonio Krüger, and Pascal Lessel. 2022. Viewer types in game live streams: questionnaire development and validation. *User Modeling and User-Adapted Interaction* 32, 3 (June 2022), 417–467. doi:10.1007/s11257-022-09328-9

[59] Kelsea Schulenberg, Guo Freeman, Lingyuan Li, and Catherine Barwulor. 2023. "Creepy Towards My Avatar Body, Creepy Towards My Body": How Women Experience and Manage Harassment Risks in Social Virtual Reality. *Proc. ACM Hum.-Comput. Interact.* 7, CSCW2, Article 236 (oct 2023), 29 pages. doi:10.1145/3610027

[60] Kelsea Schulenberg, Lingyuan Li, Guo Freeman, Samaneh Zamanifard, and Nathan J McNeese. 2023. Towards Leveraging AI-based Moderation to Address Emergent Harassment in Social Virtual Reality. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–17.

[61] Joseph Seering, Robert Kraut, and Laura Dabbish. 2017. Shaping pro and anti-social behavior on twitch through moderation and example-setting. In *Proceedings of the 2017 ACM conference on computer supported cooperative work and social computing*. 111–125.

[62] Joseph Seering, Tony Wang, Jina Yoon, and Geoff Kaufman. 2019. Moderator engagement and community development in the age of algorithms. *New Media & Society* 21, 7 (2019), 1417–1443.

[63] Mel Slater, Daniel Pérez Marcos, Henrik Ehrsson, and Maria V Sanchez-Vives. 2009. Inducing illusory ownership of a virtual body. *Frontiers in neuroscience* 3 (2009), 29.

[64] Stevie Suan. 2021. Performing Virtual YouTubers. (2021). doi:10.11588/CROSSASIA.971.C12884

[65] Yuta Sugiura, Hikaru Ibayashi, Toby Chong, Daisuke Sakamoto, Natsuki Miyata, Mitsunori Tada, Takashi Okuma, Takeshi Kurata, Takashi Shinmura, Masaaki Mochimaru, and Takeo Igarashi. 2018. An asymmetric collaborative system for architectural-scale space design. In *Proceedings of the 16th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and Its Applications in Industry* (Tokyo, Japan) *(VRCAI '18)*. Association for Computing Machinery, New York, NY, USA, Article 21, 6 pages. doi:10.1145/3284398.3284416

[66] Philipp Sykownik, Linda Graf, Christoph Zils, and Maic Masuch. 2021. The Most Social Platform Ever? A Survey about Activities amp; Motives of Social VR Users. In *2021 IEEE Virtual Reality and 3D User Interfaces (VR)*. 546–554. doi:10.1109/VR50410.2021.00079

[67] Twitch. 2024. The Most Popular VRChat Twitch Streamers, January 2024. https://www.twitchmetrics.net/channels/popularity?game=VRChat

[68] Vincent van Brakel, Miguel Barreda-Ángeles, and Tilo Hartmann. 2023. Feelings of presence and perceived social support in social virtual reality platforms. *Computers in Human Behavior* 139 (2023), 107523.

[69] Amy K Way, Robin Kanak Zwier, and Sarah J Tracy. 2015. Dialogic interviewing and flickers of transformation: An examination and delineation of interactional strategies that promote participant self-reflexivity. *Qualitative Inquiry* 21, 8

(2015), 720–731.

[70] Donghee Yvette Wohn. 2019. Volunteer moderators in twitch micro communities: How they get involved, the roles they play, and the emotional labor they experience. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–13.

[71] Donghee Yvette Wohn and Guo Freeman. 2020. Audience management practices of live streamers on Twitch. In *ACM International Conference on Interactive Media Experiences*. 106–116.

[72] Donghee Yvette Wohn, Guo Freeman, and Caitlin McLaughlin. 2018. Explaining viewers' emotional, instrumental, and financial support provision for live streamers. In *Proceedings of the 2018 CHI conference on human factors in computing systems*. 1–13.

[73] Jamie Woodcock and Mark R Johnson. 2019. The affective labor and performance of live streaming on Twitch. tv. *Television & New Media* 20, 8 (2019), 813–823.

[74] Liwei Wu, Qing Liu, Jian Zhao, and Edward Lank. 2023. Interactions across Displays and Space: A Study of Virtual Reality Streaming Practices on Twitch. *Proceedings of the ACM on Human-Computer Interaction* 7, ISS (Oct. 2023), 242–265. doi:10.1145/3626473

[75] Yanlai Wu, Yao Li, and Xinning Gui. 2022. " I Am Concerned, But...": Streamers' Privacy Concerns and Strategies In Live Streaming Information Disclosure. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2 (2022), 1–31.

[76] Samaneh Zamanifard and Guo Freeman. 2019. " The Togetherness that We Crave": Experiencing Social VR in Long Distance Relationships. In *Conference Companion Publication of the 2019 on Computer Supported Cooperative Work and Social Computing*. ACM, 438–442.

[77] Samaneh Zamanifard and Guo Freeman. 2023. A Surprise Birthday Party in VR: Leveraging Social Virtual Reality to Maintain Existing Close Ties over Distance. In *Information for a Better World: Normality, Virtuality, Physicality, Inclusivity: 18th International Conference, iConference 2023, Virtual Event, March 13–17, 2023, Proceedings, Part II*. Springer, 268–285.

[78] Kexin Zhang, Elmira Deldari, Zhicong Lu, Yaxing Yao, and Yuhang Zhao. 2022. "It's Just Part of Me:" Understanding Avatar Diversity and Self-presentation of People with Disabilities in Social Virtual Reality. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–16.

[79] Kexin Zhang, Elmira Deldari, Yaxing Yao, and Yuhang Zhao. 2023. A Diary Study in Social Virtual Reality: Impact of Avatars with Disability Signifiers on the Social Experiences of People with Disabilities. In *Proceedings of the 25th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–17.

[80] Qingxiao Zheng, Shengyang Xu, Lingqing Wang, Yiliu Tang, Rohan C. Salvi, Guo Freeman, and Yun Huang. 2023. Understanding Safety Risks and Safety Design in Social VR Environments. *Proc. ACM Hum.-Comput. Interact.* 7, CSCW1, Article 154 (apr 2023), 37 pages. doi:10.1145/3579630

[81] Zhenhui Zhu, Zhi Yang, and Yafei Dai. 2017. Understanding the gift-sending interaction on live-streaming video websites. In *International Conference on social computing and social media*. Springer, 274–285.