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The Most Social Platform?
Unveiling Experiential Qualities and the Day-to-Day Use of Social Virtual Reality Applications

Cumulative Dissertation

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Abstract

Motivated by the far-reaching social distancing measures during the Covid 19 pandemic, as well as current efforts of large tech companies to find the ultimate platform for social interaction at a distance, this dissertation takes a look at the particular experiential qualities as well as the everyday value of social VR applications. Those applications use virtual reality technology to allow people to interact with each other in immersive virtual worlds, whereby they afford verbal and nonverbal communication modalities resembling face-to-face communication. By taking four different perspectives on social VR, this cumulative dissertation approaches an assessment of the provocative statement that VR is the most social platform ever existed. The four perspectives include examining virtual social touch, exploring the reasons why people already use social VR on a daily basis, revealing attitudes and behavioral patterns regarding disclosing personal information in social VR, and evaluating the virtual replication of a popular social leisure activity. The results presented in this dissertation illustrate, that current consumer VR offers access to meaningful social experiences very similar to in-person interactions, despite current technical limitations. Due to VR's immersive properties, social VR applications are technically fundamentally different from other social platforms in terms of the types of interactions people can have with each other in VR. Yet, only future work can conclusively assess to what extent this makes VR more social than alternatives assuming that VR technology and social VR offerings gain wider acceptance and use. The practical and scientific contribution of this dissertation's different perspectives lies in identifying numerous starting points for the further development of the social VR genre and the further theory-building investigation of social experiences in social VR. In addition, the results of the individual studies presented in the dissertation provide a baseline measurement against which the experience-related effects of future hardware and software developments can be measured.

Kurzzusammenfassung

Ausgehend von Social Distancing Maßnahmen im Rahmen der Covid 19 Pandemie, sowie aktuellen Bestrebungen großer Tech-Konzerne die ultimative Plattform für soziale Interaktion auf Distanz zu finden, wirft diese Dissertation einen Blick auf die besonderen Erlebnisqualitäten sowie den Alltagsnutzen von social VR-Anwendungen. Dies sind Anwendungen, die es mittels Virtual Reality Technologie erlauben, miteinander in immersiven virtuellen Welten zu interagieren und dabei auf verbale und nonverbale Kommunikationsmodalitäten der unvermittelten Kommunikation zurückzugreifen. Anhand vier unterschiedlicher Perspektiven auf social VR nähert sich diese kumulative Dissertation der Beurteilung des provokanten Statements an, dass VR die sozialste Plattform sein soll, die es je gab. Die vier Perspektiven umfassen die Untersuchung von virtuellem Körperkontakt, das Ergründen der Motive aus denen schon heute Menschen social VR in ihrer Freizeit nutzen, die Offenlegung von Einstellungen und Verhaltensmustern hinsichtlich des Teilens persönlicher Informationen untereinander in social VR, sowie der Evaluation der virtuellen Nachbildung einer populären gemeinschaftlichen Freizeitbeschäftigung. Die Ergebnisse der vier im Rahmen dieser Dissertation durchgeführten Studien deuten darauf hin, dass VR, trotz derzeit noch bestehender technischer Limitationen, Zugang zu bedeutungsvollen sozialen Erlebnissen bietet, welche dem unvermittelten zwischenmenschlichen Kontakt sehr ähnlich sind. Aufgrund der immersiven Eigenschaften von VR, unterscheiden sich social VR-Anwendungen technisch grundlegend von anderen sozialen Plattformen hinsichtlich der Art von Interaktionen, die man in VR miteinander durchführen kann. Inwieweit dies VR tatsächlich sozialer macht als andere Plattformen, kann jedoch erst in zukünftigen Arbeiten abschließend beurteilt werden, vorausgesetzt, dass VR-Technologie und social VR-Angebote in den kommenden Jahren breitere gesellschaftliche Akzeptanz und Nutzung erfahren. Der praktische und wissenschaftliche Beitrag der unterschiedlichen Perspektiven dieser Dissertation liegt in der Identifizierung zahlreicher Anknüpfungspunkte für die Weiterentwicklung des Genres social VR und die weiterführende, theoriebildende Erforschung sozialer Erlebnisse in social VR. Zudem stellen die Ergebnisse der einzelnen in der Dissertation präsentierten Studien eine Baseline-Messung dar, an der die erlebnisbezogenen Auswirkungen künftiger hardware- und softwareseitiger Entwicklungen bemessen werden können.

Thank You

I am grateful for the publicly financed education I could enjoy, which gave me the privilege to learn a lot about the subject I studied and myself. Most notable, this educational path has brought two extraordinary people into my life, to whom I cannot express my gratitude adequately enough at this point:

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I must thank Sukran and Divine for the successful collaboration in the last part of my Ph.D. studies! Only in retrospect do I realize that I missed external collaborators during my first Ph.D. years. Also, I would like to thank Prof. Guo Freeman, whom I met through Divine, and who agreed to be the second examiner of my dissertation.

Finally, I would like to thank Prof. Maic Masuch, who made my journey over the last years possible in the first place and always gave me an immense amount of freedom. He always had an open ear for my concerns and was willing to provide me with the necessary resources to achieve my goals.

List of Publications

The following publications listed in chronological order constitute the body of work of this dissertation and are included in the Appendix:

1. Philipp Sykownik and Maic Masuch. 2020. The Experience of Social Touch in Multi-User Virtual Reality. In 26th ACM Symposium on Virtual Reality Software and Technology (VRST '20). Association for Computing Machinery, New York, NY, USA, Article 30, 1–11. https://doi.org/10.1145/3385956.3418944

2. Philipp Sykownik, Linda Graf, Christoph Zils, and Maic Masuch. 2021. The Most Social Platform Ever? A Survey about Activities & Motives of Social VR Users. In 2021 IEEE Virtual Reality and 3D User Interfaces (VR '21). IEEE. pp. 546-554.https://doi.org/10.1109/VR50410.2021.00079

3. Philipp Sykownik, Divine Maloney, Guo Freeman, and Maic Masuch. 2022. Something Personal from the Metaverse: Goals, Topics, and Contextual Factors of Self-Disclosure in Commercial Social VR. In CHI Conference on Human Factors in Computing Systems (CHI '22). Association for Computing Machinery, New York, NY, USA, Article 632, 1–17.https://doi.org/10.1145/3491102.3502008

4. Philipp Sykownik, Sukran Karaosmanoglu, Katharina Emmerich, Frank Steinicke, and Maic Masuch. *2023.* VR Almost There: Simulating Co-located Multiplayer Experiences in Social Virtual Reality. In CHI Conference on Human Factors in Computing Systems (CHI '23). Association for Computing Machinery, New York, NY, USA, Article 789, 1–19.https://doi.org/10.1145/3544548.3581230

Further Publications

The following publications were also produced in the course of my doctoral studies but are not part of this dissertation:

5. Philipp Sykownik, Katharina Emmerich, and Maic Masuch. 2018. Exploring Patterns of Shared Control in Digital Multiplayer Games. In Cheok, A., Inami, M., Romão, T. (eds) Advances in Computer Entertainment Technology (ACE '17). Lecture Notes in Computer Science(), vol 10714. Springer, Cham. https://doi.org/10.1007/978-3-319-76270-8_57

6. Felix Born, Philipp Sykownik, and Maic Masuch. 2019. Co-Located vs. Remote Gameplay: The Role of Physical Co-Presence in Multiplayer Room-Scale VR. In 2019 IEEE Conference on Games (CoG '19). IEEE. pp. 1-8. https://doi.org/10.1109/CIG.2019.8848001

7. Philipp Sykownik, Felix Born, and Maic Masuch. 2019. Can You Hear the Player Experience? A Pipeline for Automated Sentiment Analysis of Player Speech. In IEEE Conference on Games (CoG '19). IEEE. pp. 1-4.https://doi.org/10.1109/CIG.2019.8848096

8. Philipp Sykownik, Katharina Emmerich, Jochen Peketz, and Maic Masuch. 2019. Blending Science and Practice: A Collaborative Approach for Evaluating the Value of Heart Rate Measurement. In Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts (CHI PLAY '19 Extended Abstracts). Association for Computing Machinery, New York, NY, USA, 211–222.https://doi.org/10.1145/3341215.3354644

9. Philipp Sykownik, Katharina Emmerich, and Maic Masuch. 2020. Like in the Good Old Times, but Virtual - A Case for Simulating Co-located Multiplayer Games in VR. In Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '20). Association for Computing Machinery, New York, NY, USA, 379–383.https://doi.org/10.1145/3383668.3419885

10. Philipp Sykownik and Maic Masuch. 2021. Developing a Framework for Designing Augmentations of Social Touch in Multiuser Virtual Reality. In Wienrich, C., Wintersberger, P. & Weyers, B. (Hrsg.), Mensch und Computer 2021 - Workshopband. Bonn, Gesellschaft für Informatik e.V.. https://doi.org/10.18420/muc2021-mci-ws16-241

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1. Introduction

My doctoral studies coincided with the Covid 19 pandemic, which highlighted the immeasurable value of technologies that connect us with others when personal meetings are not feasible. During the pandemic, far-reaching social distancing measures significantly restricted people's everyday social interactions, negatively affecting their well-being [HOP+20, GML20][1]. Consequently, technology companies have taken "advantage" of the pandemic in terms of marketing and distribution of their services tailored to connect people over distance. The videoconferencing market, for example, was challenged by a highly increased demand that led companies like *Zoom* and *Microsoft* eventually benefit from the pandemic[2]. Though, a significant purpose of such communication technologies has always been to connect us and ideally provide valuable social experiences at a distance. Those technologies shall generate feelings of a connection or social presence over distance by giving access to the actions, emotions, and thoughts of remote others. Apart from overcoming challenges during the Covid 19 pandemic, such technologies also facilitate today's flexible live models, allowing friends and family members living apart to stay in contact regardless of location and time. In addition, facing the consequences of climate change, a reduced need or acceptance for traveling may further increase the demand for ever-evolving social presence technologies.

The Most Social Platform?

Research investigating feelings of social presence over distance often refers to face-to-face (f2f) interaction as the experiential gold standard that communication technologies should simulate [HB04, OBW18]. Considering modern immersive virtual reality headsets (VR headsets from here on), simulating this gold standard no longer seems to be just future dreams. VR technology is not only capable of providing the same types of social stimuli as other technologies we are familiar with, like videoconferencing, phone calls, or text messages, but is further said to create an experience that makes you feel as if you were together with others in the same place. In short, VR promises to support natural embodied social interactions like those we are familiar with from in-person meetings. In multiuser VR applications, users interact in a shared virtual environment while being represented and visible to each other as avatars that can display social stimuli that we know from f2f interaction. For example, users can say "hello" to their microphones and hear others over earphones or shake each other's hands, enabled by movement tracking technology. These technology-based social representation and interaction paradigms lead to intuitive and natural forms of interpersonal interactions in VR that a videoconference cannot reproduce. Thereby, various research and development efforts indicate that VR experiences steadily improve

[1] WHO scientific brief, last accessed February 28th, 2023: `https://www.who.int/publications/i/item/WHO-2019-nCoV-Sci_Brief-Mental_health-2022.1`

[2] researchandmarkets market summary, last accessed February 24th, 2023: `https://www.researchandmarkets.com/issues/video-conferencing-demand-rises`

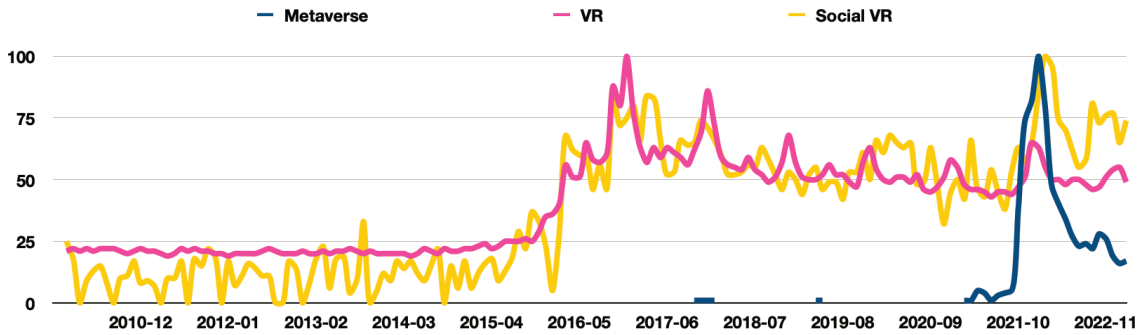

Figure **1-1**.: Worldwide, public interest in "VR", "Social VR", and the "Metaverse" over time, based on google trends. The vertical axis indicates the terms' search interest relative to their highest point in the chart. Created February 24th, 2023.

in terms of sensory fidelity, i.e., photo-realism, spatial sound, haptic feedback, and increasingly approach reality in the foreseeable future[3]. Tracking technologies are also constantly being advanced and, for example, already enable the tracking of detailed finger movements and facial expressions with consumer devices. And with advancements in computational power and the utilization of artificial intelligence, our virtual representations' visual and behavioral realism will steadily increase in the years to come. However, enabling users worldwide to interact in virtual social interactions using VR technology in their homes only became technically feasible in the past decade. In this decade, companies like *Oculus* and *HTC* launched several consumer-grade VR headsets that were considered the start of a new VR boom[4] (see Figure **1-1**) and can be considered the first generation of devices that may indicate a drastic change in how people connect over distance in the future.

A major event in the younger VR history was when *Meta*, then still *Facebook*, acquired *Oculus* in 2014[5]. Foreshadowing the long-term strategy behind this acquisition *Meta* 's CEO Mark Zuckerberg proclaimed during a townhall Q&A in Rome in 2016, that "*virtual reality and augmented reality gonna be the most social platform that has ever existed*" [6]. In fall 2021, amid the global pandemic, *Facebook* rebranded itself as *Meta*, whose mission statement as of October 2022 was: *"Giving people the power to build community and bring the world closer together"*[7]. In December 2021, *Meta* released *Horizon Worlds*, its version of a virtual social world that users can access with the brand's VR headsets. In October 2022, at its yearly company conference *Meta Connect*, *Meta* introduced its newest VR headset, the *Quest Pro*, following the popular *Quest 1* and *Quest 2*. The *Quest Pro* features integrated mimic-tracking, which is, justifiably, marketed

[3]Meta Reality Labs publications database, last accessed February 24th, 2023: `https://research.facebook.com/publications/research-area/augmented-reality-virtual-reality/?s`

[4]Financial Times article from 2016, last accessed February 24th, 2023: `https://www.ft.com/content/dae861ee-b275-11e5-b147-e5e5bba42e51`

[5]Forbes article from 2014, last accessed February 24th, 2023: `https://www.forbes.com/sites/briansolomon/2014/03/25/facebook-buys-oculus-virtual-reality-gaming-startup-for-2-billion/?sh=7ccc68fb2498`

[6]Interview from August 29th, 2016. Link to video on *facebook*, last accessed January 27th, 2023, starting at 10:07: `https://www.facebook.com/zuck/videos/10103066366848051/`

[7]Link to company information, last accessed October 25th, 2022: `https://about.meta.com/company-info/`

as a crucial next step towards a richer social experience in VR. In addition, *Meta* presented its vision of how future devices like the *Quest Pro*, with innovative software features, eventually should bring VR, augmented reality (AR), mobile phones, and desktop PCs closer together in the future, laying a foundation for the *Metaverse* [Ste03] that *Meta* wants to build. The concept of the *Metaverse* is a persistent digital world that is commonly envisioned to succeed the internet of today in that it converges today's technologies with "novel" technologies like AR and VR and also with physical reality, enabling seamless transitions between physical and virtual spaces and interactions. And in *Meta* 's vision, this very *Metaverse*, whatever it will look like exactly, is the technological infrastructure that connects us closer than anything before it [8]. Those and similar recent efforts of enterprises like *Microsoft* or *Apple* foreshadow the continuing impact of novel communication technologies on how we interact and stay in touch with each other. And based on the track records of such enterprises in terms of their products that accompany and determine our current everyday lives, a past statement like Mark Zuckerberg's as well as his company's billions of dollars investments into how it envisions the future of how people connect, certainly get some weight.

Considering the pandemic, Mark Zuckerberg's assumption of VR being the most social platform had a timeframe to prove its validity. At least, the rebranding of *Facebook* to *Meta* in 2021 kick-started public interest in the *Metaverse* (see Figure **1-1**). At the same time, *Meta* sees itself challenged by internal and public controversies on how it approaches its vision. However, although still not a commonly used technology, the global VR market sees and is expected to see a steady growth[9,10]. Correspondingly, established and new VR companies feel confident bringing new VR headsets to the market (e.g., *HTC Vive XR Elite*, *Pico 4*, *Bigscreen Beyond*, and the rumored *Apple* device). Against this background, there is an emerging ecology of consumer-grade, publicly available, and free-to-use multiuser VR applications that allow users worldwide to meet others in virtual worlds using VR headsets. And this dissertation is concerned with the question of how social those applications currently are.

1.1. Research Goals

Claims that VR could have broader implications for social interactions at a distance were made before Mark Zuckerberg [Bio06] and the social VR applications we see today are not the first working applications of their kind but rather descendants of earlier research prototypes that demonstrated the potential for social experiences in VR [BBH+90]. However, as described above, today's VR headsets and applications are available in unprecedented quality and quantity for private persons outside of technology companies and research laboratories. Against this background, this dissertation contributes a momentary assessment of the current social VR experi-

[8] Interview with Mark Zuckerberg October 2022, last accessed, February 24th, 2023: https://www.theverge.com/23397187/mark-zuckerberg-quest-pro-metaverse-interview-decoder

[9] Grand View Research market forecast from 2021, last accessed February 25th, 2023: https://www.grandviewresearch.com/industry-analysis/virtual-reality-vr-market?utm_source=prnewswire&utm_medium=referral&utm_campaign=ict_07-july-22&utm_term=virtual_reality_vr_market&utm_content=rd

[10] Fortune Business Insights market forecast from 2022, last accessed February 25th, 2023: https://www.fortunebusinessinsights.com/industry-reports/virtual-reality-market-101378

ences available to consumers. Throughout this dissertation, a slightly modified version of Mark Zuckerberg's statement, rephrased as a question, should serve as a guiding question: **Is VR the most social platform ever?** While not providing a definitive answer, this dissertation offers an informed discussion of the question based on results from two controlled laboratory user studies and two studies assessing the thoughts and behaviors of people that already use social VR in their private life. More specifically, the four publications that form the body of work of this dissertation address the following four research questions:

Study 1: What is the experiential quality of virtual social touch?
This first study [SM20] is motivated by VR's technological capabilities to visually replicate one of the most intimate forms of social interaction: social touch. By asking if virtual social body contact evokes emotional responses and what factors affect those, this study assesses whether current VR technology may afford social interaction that other communication technologies do not.

Study 2: Why do people use consumer social VR applications?
The second study assesses whether social VR applications are used due to social motives [SGZM21]. It provides insights gathered from people that already use social VR applications in their private life and indicates what they find there that other venues do not offer. Assessing those insights from today's users may allow assumptions of what impact social VR may have in the future on a broader scale.

Study 3: How do social VR users engage in self-disclosure?
The third study investigates how social VR users engage in a fundamental part of socializing, and relationship-building: self-disclosure [SMFM22]. By unveiling what users disclose to each other and what contextual factors influence their disclosure decisions, this study allows us to assess whether socializing in social VR is similar to socializing in f2f contexts.

Study 4: Can social VR replicate the experiential qualities of a popular in-person social leisure activity?
The fourth study is motivated by VR's capability to replicate popular social leisure activities and assess its potential as an alternative for in-person meetings when those are not feasible, as during the Covid 19 pandemic [SKE+23]. By comparing a virtual and a f2f version of a popular social leisure activity - playing video games in a co-located scenario - this study unveils how close the player and social experience in VR comes to the f2f gold standard.

Overall Contribution

The overall contribution of this thesis is an exploration of the experiential qualities and everyday-value of social VR applications available for consumers. This contribution stems from a mixture

of methods and data sources that considers both ends of the spectrum between research & development and real-world use cases. Further, the four exploratory perspectives offered in this dissertation unveil numerous starting-points for theory-building follow-up research. Since this work is a snapshot of consumer VR technologies available between 2018 and 2022, it only allows a limited assumption of how social VR may contribute to social connections over distance in the future. However, assuming an increasing acceptance of technology and widespread use in the coming years due to technological advancements and lower entry barriers, such a snapshot eventually provides a benchmark for future research in this area. Researchers and developers of future social VR applications can refer to this benchmark to reevaluate how individual technical advances affect social VR user acceptance, behavior, and experiential outcomes.

1.2. Outline

This cumulative dissertation is divided into a synopsis consisting of the three parts listed below, plus the Appendix, which contains the publications that make up the body of work underlying the synopsis.

1) Background

In chapter 2 the theoretical underpinnings of immersive social VR experiences are covered. The concepts behind the feelings of being present in a virtual place, embodying a virtual representation, and feeling in presence of other people despite spatial distance are explained (section 2.1). In addition, the chapter provides a definition of the genre of consumer social VR applications and an overview of a small selection of such applications (section 2.2). The chapter concludes with an overview of literature related to commercial social VR from 2018-2023 (section 2.3).

2) Body of Work

In chapter 3, the four publications that comprise this thesis's body of work are summarized and related to the previously defined guiding research question. The summary includes the motivation behind each study, the specific research questions and findings, and a brief judgment of its contribution. Since this is a cumulative dissertation, the summaries are focused. A complete evaluation of this dissertation thus requires reading the publications, each of which also stands on its own (Appendix A).

3) Discussion & Conclusion

In chapter 4 the main findings of the individual studies are related to each other and discussed in the context of the guiding research question. In addition, limitations and broader areas for follow-up research are indicated. In chapter 5, a concluding statement is formulated concerning the guiding research question.

2. Background

This chapter covers the theoretical basics and recent literature landscape relevant to this dissertation. Starting with the concept of sensory immersion, the following sections show why VR is an exciting medium for social interactions in the first place by reviewing the fundamental experiential qualities of VR. Subsequently, consumer social VR is defined and supplemented by a small overview of selected applications. This chapter concludes with a review of recent social VR literature that helps contextualize this dissertation's body of work presented in the next chapter.

2.1. Foundations of Immersive Social Experiences

To understand what potentially sets social experiences in VR apart from other digital social places, an understanding of VR's technical capabilities and experiential qualities is required. Due to these technological and experiential factors, VR technology holds the potential to induce a sense of togetherness that other technologies cannot achieve. The foundation of this sensation is a sensory immersion which allows for four subjective illusions of VR to occur [SBB+22]: the illusion of place and plausibility, the illusion of virtual body ownership, and the illusion of social presence. As those are commonly recognized concepts in VR research [SBB+22], the following pages focus on providing definitions for them and deliberately do not review individual studies on their effects and determinants.

2.1.1. Being Sensory Immersed

The main selling point of VR is that it creates immersive experiences. Saying a medium is immersive can refer to two different forms of immersion. It is either a psychological state of mental engagement in the mediated environment [WS98, LDC+00], be it a video game, movie, audio, or even a printed book. Or, it refers to objective technological specifications of a medium like VR [SW97, Sla09, SBW17, SBB+22]. In a VR context, immersion, or immersive experience, is often used in the latter sense and refers to the degree of sensory immersion that VR headsets provide. Thereby, VR is said to be more immersive than other technologies like conventional monitors. What makes a VR headset more sensory immersive than, e.g., a TV screen is that it addresses user senses inclusively, i.e., it does not simply display visual and auditory cues but also excludes external stimuli from a user's perception by placing the output devices close to a user's eyes, and ears [SW97, Sla09]. Further, modern VR headsets do this increasingly in a panoramic way by providing a wide field of view, and spatial audio [SW97, Sla09]. By adding technologies like haptic feedback devices, VR headsets are also more extensive in the number of senses they can address [SW97, Sla09]. Further, VR is a highly interactive medium that does not simply address several sensory channels in an inclusive and panoramic manner but matches the sensory output information with the input information user provide with their body movement. This matching ideally creates sensorimotor contingencies by coupling tracked user movements with a coherent

and plausibly responsive virtual world perceivable through a coherently integrated stream of sensory perceptions. E.g., a VR headset would allow you to "[...] turn your head or bend forward and the rendered visual images ideally change the same as they would if you were in an equivalent physical environment" [Sla09]. Eventually, sensorimotor contingencies between user input and VR output are a prerequisite for feeling "being present" in the virtual world and naturally interacting with it [SW97, Sla09].

A modern consumer VR headset like the popular *Meta Quest 2* usually has the following immersive characteristics. It tracks its rotational movement and positional changes relative to its physical surroundings. Additionally, it can precisely track hand and finger movements and translate them into VR. As an alternative to the hands and fingers, the headset can also track the activity of two single-hand controller devices that provide more traditional input modalities via buttons and thumbsticks. Further, microphones can process voice input. The recently launched *Meta Quest Pro* can additionally track eye movements and facial expressions. Other devices, like the *HTC* VR headsets, allow tracking even more physical objects by extending them with tiny tracking devices attached to body parts and other things. As described above, modern VR headsets are tailored to integrate those movement-based input channels with visual and auditory output channels, i.e., output information displayed on the two headset lenses that generate a stereoscopic image and integrated speakers that create spatial audio. The controllers additionally provide a haptic feedback channel in the form of vibrations. This input and output integration enables users to interact within a virtual environment based on body movement naturally. E.g., due to hand and finger tracking, users can precisely control a virtual representation of their hands, allowing them to touch and pick up virtual objects just like they would in the real world. Eventually, this would, for example, enable them to operate a simulated desktop PC in VR, i.e., sitting at a virtual desk, using a virtual mouse and keyboard, and looking at a virtual monitor. This simulation capability of VR makes it objectively more immersive than technologies that can not simulate the operation of a VR headset in the same natural way [Sla09].

In summary, in the context of this thesis, the term immersion, or immersive, is used in the sense of sensory immersion. And sensory immersion is the objective extent to which a system like a VR headset supports sensorimotor contingencies between user actions and changes in the mediated environment. Eventually, sensory immersion or the set of supported sensorimotor contingencies define the boundaries where a feeling of being present in a virtual world can occur [Sla09, SBB+22]. Due to their functioning, VR headsets are highly immersive and thus can induce intense manifestations of this feeling.

2.1.2. Feeling Present in Immersive Virtual Worlds

Besides immersion, in VR and virtual environments, the feeling of presence is another fundamental concept, commonly defined as a feeling of "being there" in a virtual environment [SBW17]. Inducing a sense of presence can be considered as the goal of sensory immersion, i.e., an immersive device should create a feeling of presence, and the intensity of this sensation could be used as an evaluative metric for it [SBW17]. Correspondingly, sensory immersion is a technical prerequisite for presence [SBW17, Sla09, SBB+22]. In an extensive review article, Skarbez et al. [SBW17] point out that the vast presence-related literature provides numerous definitions of the

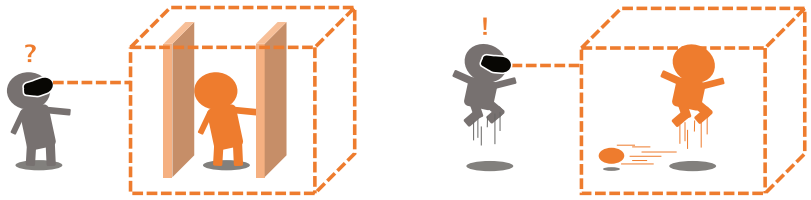

Figure **2-1**.: VR headsets can create an illusion of being placed in a virtual environment despite knowing you are not really there and cause you to react to virtual objects as if they were real.

concept that lead to different usages depending on a definition's nuances. However, Skarbez et al. observed that the feeling of presence is often used to refer to a perceived realness of a mediated environment. Eventually, they argue, to instead use the term place illusion proposed by Slater [Sla09, SBB+22] to refer to the feeling of "being there," to reduce confusion around the concept of presence due to the number of different definitions [SBW17]. Accordingly, this dissertation uses the term place illusion to refer to the subjective feeling of being in a virtual environment [Sla09, SBB+22].

Place illusion is only one sub-component that eventually contributes to the perceived realness of a mediated environment [SBW17, Sla09, SBB+22]. And as indicated, place illusion can result from sensory immersion, i.e., sensorimotor contingencies. Skarbez et al. describe this relationship by referring to a virtual library, where you turn around to see the bookshelves continuing behind you: the VR headset would generate precisely the view you would expect to see if you were actually in a physical library, turning your head [SBW17]. However, the illusion does not require a virtual environment to be a replica of a setting that exists in physical reality but also applies to fantastic and imaginative worlds [SBB+22].

Slater additionally introduced the concept of plausibility illusion: the extent to which the user perceives the virtual environment as a plausible and coherent world in how it behaves and reacts towards the user so that he believes that the virtual events are really happening [Sla09, SBB+22]. Referring back to the virtual library, imagine you see several people sitting there reading their books as you suddenly sneeze loudly into the VR headset's microphone. If now some virtual people turn their heads up, looking at you, saying "bless you" or "pssst", this would be a plausible reaction contributing to a plausibility illusion that may cause you to feel sorry for having interrupted other's concentration. However, if no one responds, the scenario would seem less plausible. In an updated discussion of how place and plausibility illusion relate to concepts introduced by other researchers in the last years, Slater et al. highlight that the illusion of plausibility is what leads to an exclamation like "This is really happening!" and causing a user to dodge falling objects in VR [SBB+22] or would motivate the user in the virtual library to excuse for sneezing. As with place illusion, plausibility is not exclusive to virtual replicas of reality, but also imaginative worlds can be plausible in how they function and react to users [SBB+22]. Place illusion and plausibility illusion are conceptually distinct and on orthogonal axes. One can feel like being placed in a virtual environment without perceiving it as plausible, and vice versa [SBB+22]. If established simultaneously, the illusion of place and the illusion of plausibility can cause VR users to respond realistically to virtual events, despite knowing that

these are not reality [SBB+22] (see Figure **2-1**).

Analogous to place illusion being defined as a result of objective specifications of an immersive system, Slater et al. highlight that plausibility illusion is also a consequence of objective, deterministic characteristics of a virtual scenario that can be purposefully implemented [SBB+22]. In the library example, this means that the behavior of virtual humans must be specified and implemented to occur when the system detects a sneeze. They highlight this deterministic view as they criticize other approaches that associate the concept of plausibility with user-dependent characteristics like user expectations or prior knowledge [SBW17] or use the term of plausibility to refer to a different concept [LW22]. Thus, similar to the confusion about the term presence, there is an ongoing scientific discourse about models of plausibility, what factors contribute to it, and how deterministic those factors are [SBW17, SBB+22, LW22] and how it may relate to a concept of presence when considering not only VR but also augmented and mixed reality scenarios [LW22]. In summary, although VR research has dealt with the concept of presence since the early 1990s, it is a very relevant topic with new academic controversies highlighting the need for further research [SBB+22].

In summary, in this thesis, the commonly used concept of "being there" is considered as resulting from the simultaneous emergence of the illusions of place and plausibility within the boundaries set by the sensory immersion of a VR headset [Sla09, SBB+22]. The illusion of place makes users feel like they are in a virtual environment, and the illusion of plausibility causes them to respond to virtual events as if they were real.

2.1.3. Embodiment of Virtual Avatars

A third fundamental illusion of VR [SBB+22] relates to avatars, the virtual representations of users in a virtual environment, and how VR technologies let us control them. Usually, VR applications provide users with a first-person perspective on their avatars that can represent the whole or only parts of their physical body as illustrated in Figure **2-2**. In other words, users embody an avatar in VR. Thus, if provided with a full-body representation, users that look down in VR would see a virtual torso, arms, and legs. But VR does not only provide us with a virtual representation that we can see, but also allows us to control it naturally. As modern VR headsets utilize real-time tracking technologies, they can track how we move parts of our physical body and apply this data to our avatar so we can see how, e.g., our virtual legs and arms move synchronously with their physical counterparts. Thus, VR headsets can simulate how we integrate visual and proprioceptive perceptions of our physical body by integrating the visual stimuli of our virtual representation with the proprioceptive sensations of our physical body. And similar to the illusions of place and plausibility, the objective technical condition of embodying an avatar can lead to an illusion of ownership, or virtual body ownership, i.e., a feeling that the displayed virtual body is our own body, although we know that it is not [SSSVB10, SBB+22].

Analogous to the illusions of place and plausibility, the illusion of virtual body ownership affects how users experience VR scenarios and respond to virtual stimuli related to their avatars. For example, virtual threats can trigger subconscious neural mechanisms representing intentions to pull away one's physical hand [GFPRFS14], and virtual social touches directed to an embodied avatar can elicit cognitive and emotional reactions in users [SM20, FLTA21]. Another popular

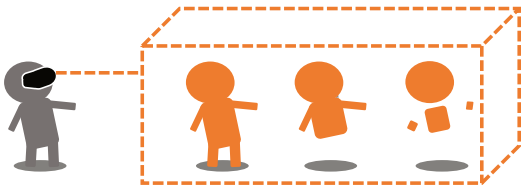

Figure **2-2.**: In VR, users are represented by avatars that can be either full-body representations or only represent parts of a human body. The degree of representation in a VR application often depends on the tracking technologies used and how well software algorithms can animate the different avatar parts.

research area in this context is related to the effects of embodying virtual bodies with different traits than one's physical body. A reliable [RBLG20] effect in this context is the Proteus effect, which leads to a change in user behavior in the virtual environment that corresponds to traits of one's digital representation [YB07]. Examples of this effect are behaving more intimately with others when embodying attractive avatars, or more confident when embodying taller avatars [YB07], performing better at exercises when embodying a professional athlete [SEKA22] or a muscular virtual body [KKS+20]. Further, according to the self-avatar follower effect, the movement of an embodied avatar can subconsciously affect users' motor behavior [GFCO+20]. Other research indicates that embodying avatars can subsequently affect cognitive processes outside of VR, like reducing implicit racial biases [PSAS13, BBN+20].

As a contribution to the illusion, several factors are researched and discussed in the literature, including the perspective or self-location in relation to the avatar, multisensory contingencies between vision and proprioception, movement and tactile stimuli, control paradigms, tracking fidelity, avatar realism, and appearance [MS13, GFP18, RL20, FALH20]. Embodiment studies in VR often use humanoid avatars whereby the selected factors listed above are manipulated. However, the illusion of virtual body ownership was also shown to be induced by embodying animal avatars [KCK18, KCEK19]. Eventually, current literature indicates that using a first-person perspective combined with a control paradigm that supports visuo-motor synchronous control over an embodied avatar are the essential factors for inducing the illusion [MS13, GFP18, FALH20, SBB+22]. However, appearance-related factors like realism and customization, are also frequently researched and found to affect the illusion of body ownership [LLL15, LRG+17, WGR+18]

Separated from the theoretical background, avatars in VR, especially multiuser VR, have a very practical relevance. On the one hand, avatars enable users to see each other in a shared virtual environment and, thus, to arrange their spatiotemporal relationship. Second, if avatars are distinguishable from each other, e.g. because users can customize them, they enable users to be identifiable and create and express a virtual identity. And third, depending on how much a particular avatar system supports it, avatars can display the non-verbal communication stimuli we use in f2f interaction. For example, by transmitting specific body movements into VR, we can see where other people are looking, whether they are waving to us or talking with others and not paying attention to us. Thus, avatars provide a familiar canvas for naturally displaying

socially relevant information in VR.

In summary, embodying avatars in VR and having natural control over them can induce an illusion of virtual body ownership - the feeling that this virtual representation is one's own body despite knowing it is not [SBB+22]. At the same time, it is a means to display socially relevant information, such as identity and nonverbal communication cues, that form the basis for natural interaction with other users in VR.

2.1.4. Social Presence Over Distance

Based on the above experiential foundations of VR, we can illustrate why VR is particularly suited for mediating social interaction naturally. Imagine three VR users located at different places in the world who are individually traveling through different virtual worlds and experiencing place illusion, plausibility illusion, and the illusion of virtual body ownership. Due to the illusions, they all tend to behave in those virtual worlds as if they were actually there and as if everything in VR was really happening. Suddenly, they arrive in one world altogether and are visible to each other due to their avatars (see Figure **2-3**). Instinctively, they approach one another, shake virtual hands and talk about their experiences in the other worlds, laughing together and having a good time. During this interaction, a fourth illusion [SBB+22] is likely to emerge: the illusion of "being there together" with the others in the virtual world.

In computer-mediated communication, this illusion is commonly studied as the construct of social presence, which can be considered as one "goal" of communication technologies - we use communication technology to perceive others as being close and connected to us, although they are physically remote. The construct of social presence has its roots in social psychological models of non-mediated interpersonal communication [BHB03] and was applied by Short et al. [SWC76] as a framework to research social interaction in the context of computer-mediated communication [BHB03]. Initially defined as "The degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships,[...]" (p.65)[SWC76], the current body of literature provides numerous conceptualizations and measurement instruments of social presence. Although commonly [OBW18] referred to as the sense of "being with another" (p.456)[BHB03], consent on a definition, operationalization and measurement of social presence is subject to ongoing academic discourse [BHB03, HB04, SZ21, TMG+22, HHB22].

Historically, two perspectives shaped how research studied social presence and its determinants. A medium-centric perspective [OBW18] relates to the early conceptualizations of social presence and the media richness theory and assumes that a medium's capacity to display rich social cues determines the extent of social presence, or intimacy and immediacy, it can induce [SWC76, DL86]. This view implies that certain types of media generally cause higher levels of social presence than others and probably leads to f2f interaction being commonly used as a gold standard that mediated communication should simulate [OBW18]. A contrasting user-centric perspective [OBW18] relates to the social information processing theory and assumes that the experiences social presence, or intimacy also depends on users' capabilities to adapt to the communicative affordances of a medium, and the time they have to communicate using a medium [WAL92, WAL96]. Consequently, this theory proposes, that computer-mediated communication can lead to the same intimate interpersonal relationships as f2f communications, if users

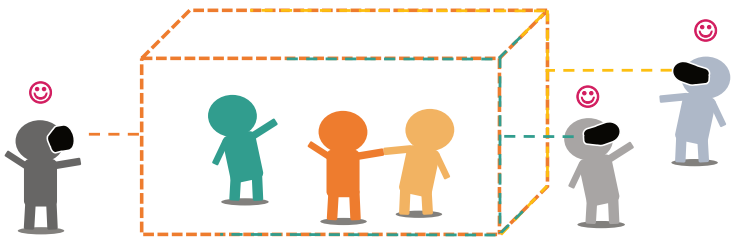

Figure **2-3**.: VR headsets can create an illusion of being together with others in a virtual environment despite knowing you are not really there with them and cause you to react to virtual others as if they were real.

have enough time to use it and adapt to it. Yet, it pays attention to the influence of a medium's technical specifications. In conclusion, considering both the medium's specification and users' adaptation strategies results in the most nuanced perspective on social presence [OBW18]. Accordingly, a comprehensive review of social presence literature (not exclusive to VR research) unveils that the subjective perception of social presence depends on immersive (e.g., modality, visual representation, interactivity), contextual (e.g., physical proximity, task type, identity cues), and individual factors (e.g., age, gender, psychological traits) [OBW18]. Thereby, considering recent technological advancements regarding the support of natural non-verbal communication cues like facial expressions, gestures, and postures, social VR applications are highlighted to have novel implications for the domain [OBW18]. Eventually, the above factors affect certain proposed sub-dimensions and behavioral indicators of social presence that researchers can then assess in experiments. For example, the self-report networked minds measure of social presence proposes the subdimensions of mutually perceived co-presence, attentional allocation, perceived message and affective understanding, and the perceived affective and behavioral interdependence [HB04].

Analogous to the illusions of place, plausibility, and body ownership, a sense of social presence eventually affects how users feel, think, and behave in a mediated social interaction, i.e., the mediation would lead to social influence effects. In this regard, the social influence model proposes that the size of social influence effects is an additive function of the intensity of the perceived social presence and behavioral realism during the interaction [BLB$^+$02]. Thereby, behavioral realism refers to characteristics and behavioral cues of avatars to "produce situationally and socially appropriate verbal and nonverbal responses", and that enable others to decode and interpret those responses [BLB$^+$02]. It is important to note that although contributing to behavioral realism, the graphical realism of avatars (i.e., anthropomorphic and photographic realism) is assumed to be less critical to contribute social presence, or social influence effects [BLB$^+$02, OBW18].

Although recent technological advancements let VR headsets track and display non-verbal communication channels like eyes, fingers, facial expressions, gestures, and body posture in VR, those cues can also (and still better) be mediated by a video call. However, VR is technically different from a video call because it situates social cues within a co-inhabited three-dimensional reference space. Thus, VR introduces a spatial component to mediated communication that serves as a natural interaction context and resembles f2f communication. Because of this spatial component, VR enables specific social interactions that depend on the spatiotemporal relationship between

users, like touching each other [SM20], sitting together on a virtual couch [SKE+23], or adjusting interpersonal distance according to specific personal space zones [BPB20, WLV+21, WOGG+22]. Other non-immersive media can not easily reproduce those types of interaction. To conclude the review of the fundamentals of immersive social experiences:

As a consequence of the illusions of place, plausibility, and virtual body ownership, multiple users that meet together in VR and are under the effect of those illusions can succumb to the illusion of social presence - they feel as if they are together at the same place, despite knowing they are physically apart [BHB03, OBW18, SBB+22]. This illusion benefits from VR's technical properties, namely the natural representation of nonverbal behavioral stimuli through an avatar and within a three-dimensional space. In this space, users are within a dynamic spatiotemporal relationship that corresponds to a f2f scenario and thus can lead to similar social influence effects.

2.2. Consumer Social VR

The illusions just introduced characterize VR experiences and, in combination, are what makes the technology particularly interesting for mediating social interactions. With this knowledge, this section now looks at the kind of applications this dissertation is concerned with specifically: consumer social VR applications.

Broadly, social VR refers to VR experiences where multiple people interact with each other in immersive virtual environments using VR technology. Social VR users are commonly represented as avatars that afford verbal and nonverbal communication modes that mimic f2f interaction [Per16, MS18, MSMSMI18, MSKI19, JSY+19, KMSI19]. As laid out in the Introduction, this thesis specifically refers to a collection of applications that establish the genre of consumer social VR. Consumer social VR applications are publicly available, typically free-to-use, and developed for consumer-grade VR head-mounted displays. Thus, they target private users using them in leisure activity contexts.

Many authors dealing with (consumer) social VR applications note that they have their origin in the domain of Collaborative Virtual Environments (CVEs) (e.g., [MSMSMI18, MS18, MSKI19, JSY+19]). In that sense, social VR can be considered the technological successor of early text-based multiuser dungeons (MUDs) and 3d virtual worlds like *Second Life* that do not employ VR technology but desktop-based input and output technologies, like a mouse, keyboard, and monitor.

However, there is a specific technological precursor for the consumer social VR applications we see today: *Reality Built for Two* (RB2) [BBH+90]. In the late 1980s, the technology company *VPL Research* introduced RB2 as the first VR system allowing more than one user to simultaneously walk through a virtual world. This system integrated several of the company's technologies, providing the following features: a fully immersive visual experience, full-body motion tracking, and three-dimensional audio. Although it took over three decades until consumer social VR became a distinctive genre of VR applications in which companies like *Meta*

and *Microsoft* engage, RB2 combined the experiential features that still build the core of today's social VR experiences.

Although there are fundamental similarities, a brief review of current consumer social VR applications indicates that they can roughly be distinguished based on the specifics of their implemented avatar systems and the number and types of activities they offer. Social VR literature provides descriptions of various platforms' avatar systems that highlight how different applications provide varying capabilities related to in-world avatar customization, avatar import features, the use of humanoid or other avatar styles, and the support of communication features like automated facial expressions [KMSI19, THB20]. In terms of activities, social VR users can, i.a., engage in having conversations, hangouts, or intimate meetings with strangers or acquaintances in private or public spaces, playing integrated or community-made games, creating and exploring different worlds, watching video content, listen to music, and gathering for social events such as parties [MF20, SGZM21, SMFM22, BAH22]. Each platform may have a different focus.

While there is an extensive number of applications that more or less could be considered as social VR[1] and thus as spiritual successors of RB2, the following paragraphs briefly describe only some selected[2] popular applications to illustrate what those platforms offer and in what aspects they can differ.

AltspaceVR

AltspaceVR was released in 2015 and acquired by *Microsoft* in 2017. It offered a variety of experiences, such as chatting with others, playing games, and participating in or hosting live events such as open mic nights, improvised comedy, meditation, and yoga. *AltspaceVR* was more popular among adults and focused on live events and the blending of entertainment and professional offerings. Over the years, *AltspaceVR* went through significant graphical iterations of the avatar aesthetics. Still, it employed stylized avatars with limited anatomical features, including a head, hands, and torso. According to *Steam*, estimations of *AltspaceVR* owners range from around 20,000 to 700,000[3]. On January 20th, 2023, *Microsoft* announced that *AltspaceVR* would be shut down by March 10th, 2023, as a consequence of its efforts to advance its business-oriented offerings for immersive social experiences before it eventually will provide consumer experiences again[4].

Horizon Worlds

As described in the Introduction, *Horizon Worlds* is the culmination of *Meta*'s efforts to build their version of a VR-based social platform. At the same time, it may be the most publicly known, observed, and controversial platform listed here, given the public and political discourse about how *Meta* handles data privacy in general. For example, there were early reports of harassment

[1] Blog by Ryan Schultz with a comprehensive and updated list of platforms, last accessed February 9th, 2023: `https://ryanschultz.com/list-of-social-vr-virtual-worlds/`

[2] Based on being relevant in two of our studies and on media coverage in case of Horizon Worlds.

[3] Link to Steam Charts, last accessed February 9th, 2023: `https://steamdb.info/app/471710/charts/`

[4] Link to the announcement, last accessed on February 9th, 2023: `https://altvr.com/sunset/`

in *Worlds*[5], as well as leaked internal reports indicating that *Meta*'s employees avoid using the platform themselves[6]. Though, despite the company's background, the platform is very similar to other platforms in terms of the avatar systems and activities it offers. Users can socialize in public hub worlds, collaborate to build custom virtual worlds and activities, and participate in games and events. The stylized avatars are of limited anatomical features (i.e., no legs), but, in contrast to *RecRoom* and *AltspaceVR*, have arms. Additionally, the avatars support the hand-, finger- and face-tracking capabilities of *Meta*'s VR headsets. Similar to other platforms, there are no official data on user numbers. However, leaked internal reports indicate that the platform struggles to keep users actively engaged, as *Meta* decreased their goal of monthly users from 500,000 to 280,000 in the course of 2022[7]. Horizon Worlds was released in December 2021.

Neos

Neos, released in 2018, prioritizes features for sophisticated internal content creation, including worlds, avatars, and interactions within VR. What sets *Neos* apart from other platforms is its engagement in educational contexts, like, e.g., astronomy or pediatric life support[8], as well into integrating a cryptocurrency to build a complex in-world economy. Due to the flexibility offered by the platform's tools, avatars in *Neos* can have all types of styles and appearances, similar to *VRChat*. According to *Steam*, estimations of *Neos* owners range from around 30,000 to 500,000[9].

RecRoom

RecRoom was released in June 2016, with a design inspired by a recreational center where players meet to engage in diverse gameful activities or hang out in a public area to socialize with others. Players can group up and access pre-made and community-made gaming experiences from this main public area. The avatars in *RecRoom* have simple humanoid features with limited anatomy, i.e., only heads, hands, and torso. The platform is targeted at and popular among younger users as it is a member of the *kidSAFE* seal program, uses comic-style aesthetics, and focuses on game activities. According to the platform's press information, it has accumulated over 82 million users over the platforms lifetime with 29 million active players in the first quarter of 2022[10]. According to *Steam*, estimations of *RecRoom* owners range from around 1 million to 2.8 million[11].

[5] Link to techdirt, last accessed on February 9th, 2023: `https://www.techdirt.com/2021/12/28/grope-metas-space/`

[6] Link to The Verge, last accessed on February 9th, 2023: `https://www.theverge.com/2022/10/6/23391895/meta-facebook-horizon-worlds-vr-social-network-too-buggy-leaked-memo`

[7] Link to The Verge, last accessed on February 9th, 2023: `https://www.theverge.com/2022/10/15/23405811/meta-horizon-worlds-losing-users-report`

[8] Link to Neos VR, last accessed February 9th, 2023: `https://neos.com/features#educate`

[9] Link to Steam Charts, last accessed February 9th, 2023: `https://steamdb.info/app/740250/charts/`

[10] Link to RecRoom press information, last accessed on February 9th, 2023: `https://recroom.com/press`

[11] Link to Steam Charts, last accessed February 9th, 2023: `https://steamdb.info/app/471710/charts/`

Figure **2-4.**: The review of social VR literature covers four areas.

VRChat

VRChat's focus is on user-generated content, particularly on creating custom avatars. Its avatar system offers one of the most advanced customizations compared to other social VR platforms like *Recroom* and *AltspaceVR* as users can model and modify their avatars in external development applications like *Blender* and *Unity*. Avatars ins *VRChat* can take any form, from realistic humanoid representations to characters from pop culture to abstract forms like cardboard boxes. *VRChat* is especially known for its "wild west" atmosphere that fosters individual and creative expression utilizing avatars, community-designed worlds, and activity-based community building like dance communities. According to *VRChat*'s press kit information, the platform accumulated millions of users since 2015[12]. Based on the *Steam* database, estimations of *VRChat* owners range from around 4 million to 20 million[13].

2.3. Social VR Research

Having reviewed the experiential aspects that lie mainly in the purely technical properties of VR technology and some popular consumer applications, we now turn to a review of recent social VR literature that covers design aspects, user experiences, and evaluations of laboratory multiuser VR prototypes Figure **2-4**. The focus of this review is deliberately limited to papers published between 2018 and 2023 that represent the technological state of the art of consumer VR technology available during this period. Further, since consumer social VR platforms have only become widespread during these last years, studies on this specific topic have only begun to appear during this period. Consequently, this review intentionally does not include literature on earlier or general CVE research.

Nonetheless, this section will begin with a look at an earlier and one of the first systematic investigations of long-term social interactions in VR [BY06]. Still framed within CVE research, this study examined interaction during individual sessions over ten weeks with three participant triads. The authors found indications of a change in participants' nonverbal behavior, task performance, and subjective ratings of immersive experiences as they became familiar with the VR system. For example, they observed decreasing self-reported feelings of presence over time but increasing entitativity. Though, perceived social presence did not indicate a clear trend, although participants seemed to look significantly less at one another over time. By discussing these re-

[12]Link to VRChat press information, last accessed on February 9th, 2023: `https://hello.vrchat.com/press`

[13]Link to Steam Charts, last accessed February 9th, 2023: `https://steamdb.info/app/438100/charts/`

sults, the authors stressed that the way first-time users interact with these systems might be significantly different from those who have more experience with the technology [BY06]. Consequently, investigating novel technologies with participants that have not become familiar with them inherently introduces a methodological limitation that should be considered when interpreting study results to draw general conclusions.

Therefore, rather than solely looking at user experiences, the following literature review starts with studies on the design of current social VR applications.

2.3.1. The Design of Consumer Social VR

The 2018 work of Joshua McVeigh-Schultz et al. marks the beginning of current consumer social VR research [MSMSMI18]. The group systematically tried out five popular applications to examine what design areas shaped their social experience. In doing so, they also raised the fundamental question of whether there were similar approaches across individual applications in promoting or limiting social experiences [MSMSMI18]. Their goal was to define broader categories of design areas that would guide further investigation to understand how social VR can be designed to be social. They found that the individual platforms are sometimes more and sometimes less similar regarding particular features that influence sociality differently. For a more structured look at the differences, they framed their early discussion of those differences within the design areas of user onboarding, virtual space and navigation, and social mechanics. For example, they indicated that the design specifics of publicly accessible lobby environments create different social atmospheres during onboarding or exploration of virtual spaces. Further, referring to navigation features, the mode of locomotion combined with personal space mechanics determines how controlled, and close users can get spatially in VR. Furthermore, social mechanics like shaking hands to befriend others directly stimulate embodied social experiences in *RecRoom* whereas in other platforms, those affordances are missing [MSMSMI18].

As seen from Table **2-1**, McVeigh-Schultz et al. have continued their work on systematizing basic design approaches in social VR through two additional studies. In continuation of their previous self-experience study, they discussed their earlier findings and questions regarding general platform approaches to sociality with platform designers and industry experts in one study [MSKI19], and design strategies related explicitly to avatar systems, again with industry experts, in another study [KMSI19]. Those interviews validated their initial observations that the design areas of place aesthetics, embodied affordances, and social mechanics are integral contributors to deliberately shaping sociality in VR. Further, the interviews conveyed strategies for shaping social norms and mitigating harassment as additional fundamental design areas [MSKI19]. Thereby, as the genre of consumer social VR was and still is emerging with platforms having individual approaches to sociality, McVeigh-Schultz et al. highlighted the need to systematically identify design decisions to be able to validate the proposed impact on social experiences by comparing them with user-centered studies [MSKI19].

The avatar-related interviews indicated that different platforms' avatar systems might differ in integrating features related to embodied locomotion, avatar aesthetics, personal space, social mechanics, and virtual identity [KMSI19]. The aspects of embodied locomotion, personal space, and social mechanics directly link to the general design areas the authors have previously identified that shape sociality in social VR and highlight the fundamental role of avatars for the overall

Table **2-1**.: Overview of consumer social VR application design studies.

Year	Topic	Findings	Method	N	Reference
2018	social VR design ecology	different design approaches for sociality in terms of onboarding, space and navigation, and social mechanics emerge	autobiographic landscape research	5 (platforms)	[MSMSMI18]
2019	design of Avatar Systems	high-level design consideration areas of avatar systems include: embodied locomotion, aesthetics, personal space, social mechanics, virtual identity	expert interviews	11	[KMSI19]
2019	design strategies to support sociality in VR	design consideration areas for shaping sociality include: aesthetics of place, embodied affordances, social mechanics, shaping social norms, mitigating harassment	expert interviews	11	[MSKI19]
2019	taxonomy of social VR design	taxonomy identifies social VR features pertaining to The Self, Interaction with Others, and The Environment	literature & platform review	29 (platforms, prototypes)	[JSY+19]
2020	nonverbal communication mechanics in social VR	(i) platforms offer different default features that relate to movement, facial control, gesture & posture, but (ii) there is pausity of mechanics to control mimics, posture, pose, and social status	textual analysis & platform testing	10 (platforms)	[THB20]
2021	sociality beyond reality	social VR invites to design speculative forms of sociality related to social rituals, social augmentations, embodied communication, and its integration into everyday life	literature review, prototyping, speculative fiction	-	[MSI21]
2021	usability in social VR applications	(i) several general usability challenges identified: communication coordination, input device control, menu design, spatial navigation, object identities, mutual awareness, precise control, personal space bubble, room coordination, (ii) platform-specific issues	remote user study	17 & 6 (users & platforms)	[LS21]
2022	uncanny valley & social VR avatar styles	avatar styles vary among social VR applications and lead to various perceptions of likability, humanness, and eeriness	survey study & lab-based user study	109 & 27	[HPDW22]
2023	designing consent in social VR	there is a need for consent mechanics to mitigate harm in social VR	participatory design workshops	18	[ZC23]

social experience in VR.

Although VR technology is generally said to provide communicative affordances that mimic f2f interaction, platforms may actually support quite limited or different nonverbal communication stimuli [THB20]. Eventually, the available communicative affordances on a platform depend on what VR headsets and additional hardware (like additional body trackers) a platform supports and how developers succeed in finding software-based workarounds for simulating specific stimuli that the VR hardware can not track (like triggering face animations based on voice tonality or hand gestures) [THB20]. In particular, the study of Tanenbaum et al. unveiled a lack of features that grant precise control of virtual mimics, posture, and social status [THB20]. However, newer VR headsets, like the *Oculus Quest Pro*, now support face tracking and thus mimic control

in VR. Platforms only need to utilize those hardware features. A recent study that conducted a platform comparison focusing on avatar aesthetics found that the various default styles across platforms appear variably human, likable, and eery and consequently attract or deter users to different degrees [HPDW22].

Jonas et al. [JSY+19] offered another take on systematizing the discussion, research, and guidance of social VR design, and, similar to McVeigh-Schultz et al., undergone testing of consumer social VR applications, but additionally reviewed custom lab prototypes for multiuser VR experiences described in the research literature. They argue for including both perspectives because platform developers and researchers can learn from each other and identify novel approaches to features or research questions if they are informed about what the other side is doing. Thus, they integrated their findings in a preliminary taxonomy of social VR application design that clustered all the features they found in consumer applications, and research prototypes into three design categories: features pertaining to the self, to the interaction with others, and the interaction with the environment [JSY+19][14]. While the taxonomy integrates well with the design areas identified by McVeigh-Schultz et al., it further provides two layers of sub-categories for each design category (specific features & feature variations) and refers to examples from consumer applications, and literature [JSY+19].

Mirroring the young age of the genre and the different approaches of platform developers, not only to social interactions but also to basic functionality, a recent user study reveals fundamental, common usability issues that make it particularly difficult for new users to access social VR [LS21]. Those issues are related to, i.a.: coordinating group communication, effectively controlling VR input devices, comprehending and navigating menus, navigating virtual space, or establishing mutual awareness. Additionally, each platform has revealed platform-specific issues [LS21].

More recent efforts in this research area seem to evolve around systematizing the design of mechanics for isolated facets of social interaction, like the process of giving or denying consent for social interaction, as a strategy for harm mitigation [ZC23].

Concluding this first literature review, we again refer to McVeigh-Schultz et al.. As a counter perspective to a common understanding of VR as a technology to simulate f2f experiences, they re-opened a case for how social VR should transform social experiences beyond what f2f interaction offers [MSI21]. This perspective is not new, and the authors praise previous discussions, and showcases of transforming social experiences beyond reality [HS92, BBL+04, RBK+19]. However, their proposal was situated in the context of the Covid 19 pandemic and within the grown consumer social VR landscape. Thus, they benefit from the increased public interest in novel communication technologies and today's technical capabilities. More specifically, they highlight how social VR invites to radically speculate about how VR meetings can genuinely differ from f2f meetings in an enriching manner if e.g., the technological affordances ask users to create novel social rituals or if social interaction is augmented in a way that makes visible aspects of it that are intangible in f2f interaction [MSI21]. They complement their argumentation by presenting several consumer social VR features but also prototypes they developed and partially evaluated that showcase their understanding of "weird social" experiences (e.g., visualizations of conversational balance, gaze direction, and gestural behavior) [MSI21].

[14] Link to pre-print of updated taxonomy based on more applications, last accessed February 12th, 2023: `https://arxiv.org/abs/2201.02253`

In summary, although social VR is still an emerging ecology of consumer applications, several approaches already exist to systematize their design, discussion, and research. Further, platform developers are already employing different strategies to shape virtual sociality. In consequence, the rapid advancement of the application landscape in consumer and laboratory contexts challenges researchers and developers to keep up when further mapping the diverse design approaches and finding novel social interaction paradigms that embrace VR's technical capabilities.

2.3.2. Everyday Experiences in Consumer Social VR

Complementary to the research of social VR design, this section will give an overview of the already vast body of literature about social VR users that has been forming since 2019 and steadily answering why and how real users engage in social VR in their everyday lives (see Table **2-2** and Table **2-3**).

Divine Maloney and Guo Freeman's work, particularly, stands out in user-focused research as it includes an early series of interview studies that reveal real-world user opinions and experiences. Since 2019 they continued to cover the following diverse topics of social VR user research: the use of social VR in long-term relationships [ZF19], unveiling meaningful experiences in social VR [MF20], experiences of young users [MFR20, MFR21], non-verbal communication [MFW20], self-disclosure and privacy [MZF20], LGBTQ+ users in social VR [AF21, FA22, FMAB22, LFSA23], self-presentation using avatars [FM21], relationship-building in social VR [FA21], collaboration in social VR [FAMS22], harassment mitigation [FZMA22, SLF$^+$23], and maintaining existing close relationships [ZF23]. However, several other works, including our own, also offer insights into diverse aspects of social VR users' everyday experiences: forms of harassment in social VR [BEEDS19], user motives [SGZM21], psychological benefits [BAH22, vBAH23], self-disclosure patterns [SMFM22], dancing culture in *VRChat* [PHM22], the sensation of virtual social touch [AY22], users with disabilities [ZDL$^+$22], and the use of virtual mirrors in social VR [TB22].

This body of literature reveals that social VR offers a multitude of activities and experiences that users consider meaningful, from mundane everyday activities like sleeping together in a virtual world to engaging in educational events [MF20], enjoying diverse socializing and entertainment activities [SGZM21], or cultivating sub-cultures for specific activities like dancing [PHM22]. Despite the entertainment-focused appearance of many applications, one of the most salient motives to engage in social VR seems to be the satisfaction of social needs like meeting and staying in contact with new people, feeling a social presence or finding substitutes for a lack of real-world connections [SGZM21]. However, social VR engagement also has more "serious" drivers, like education [MF20], mental growth [SGZM21], and finding a safe place for identity exploration [AF21, FM21, SGZM21, FA22, FMAB22].

Thereby, users value that social VR provides experiences similar to f2f interactions that are meaningful and authentic [MF20, SGZM21, SMFM22]. Thus, social VR is valuable for people that seek to overcome physical distance, like partners in long-distance relationships [ZF19], people that do not have like-minded people near them [SGZM21] or people that are not allowed to meet others in-person as in the Covid 19 pandemic [MFR21, SGZM21].

The literature also indicates that diverse user groups, including children and adults [MFR20, MFR21], LGBTQ+ [AF21, FMAB22, FA22], and users with disabilities [ZDL$^+$22] value social VR

Table 2-2.: Overview (1) of user-focused studies in consumer social VR. Highlighted row belongs to this thesis' body of work.

Year	Topic	Findings	Method	N	Reference
2019	social VR in long-distance relationships	social VR provides emotions similar to f2f	social media posts analysis	650	[ZF19]
2019	harassment in social VR	(i) presence and embodiment intensifies experiences (ii) subjective definition what constitutes harassment in social VR	interviews	25	[BEEDS19]
2020	meaningful experiences	social VR affordances enable meaningful activities: full-body mirroring, mundane activities, social and mental self-improvement, education, events.	interviews	30	[MF20]
2020	minors and adults in social VR	(i) minors enjoy interactions with other minors despite risk of harassment, (ii) minor-adult interactions suffer from complex dynamics including tensions, frustration, social distancing	participatory observation on three platforms	-	[MFR20]
2020	non-verbal communication	avatar embodiment contributes natural interaction via non-verbal communication	interviews	30	[MFW20]
2020	anonymity and privacy in social VR	(i) users feel comfortable sharing emotional and general life experiences, (ii) three patterns of self-disclosure: sharing based on familiarity with others, based on anonymity, or independent from relationship, (ii) users have privacy concerns tied to technological aspects of social VR	interviews	30	[MZF20]
2021	LGBTQ users in social VR	(i) social VR as a safe space & (ii) connections like f2f	interviews & observation	8	[AF21]
2021	relationship building	avatar embodiment contributes shared experiences	interviews	30	[FA21]
2021	self presentation & perception	social VR as a space for identity exploration	interviews	30	[FM21]
2021	why teenagers use social VR	social VR provides rich social interactions beyond gaming	interviews	20	[MFR21]
2021	why users engage in social VR	(i) user engagement is mainly driven by social and experiential motives, (ii) main activities include socializing and entertainment, (iii) social VR is superior to other digital social places, (iv) there is still plenty room for improvement	survey	273	[SGZM21]
2022	psychological benefits of social VR engagement	(i) spatial & social presence predict psychological outcomes, (ii) social VR can have positive effects on user well-being	survey	220	[BAH22]

applications. However, while those different user groups already find their unique benefits from social VR, meeting all their needs equally is an ongoing challenge for platform designers. For instance, there are tensions between minors and adults [MFR20], avatars can quickly reveal users that belong to marginalized user groups [FZMA22], or do not suffice to represent queer identity [FA22], or specific disabilities [ZDL+22].

Unfortunately, diverse forms of harassment occur in social VR [BEEDS19, FZMA22]. Here,

Table **2-3**.: Overview (2) of user-focused studies in consumer social VR. Highlighted row belongs to this thesis' body of work.

Year	Topic	Findings	Method	N	Reference
2022	collaboration	avatar embodiment contributes (i) social presence & (ii) collaboration	interviews	30	[FAMS22]
2022	non-cisgender identity in social VR	social VR as a space for identity exploration	interviews	59	[FMAB22]
2022	self-disclosure in social VR	(i) users have privacy concerns, (ii) users disclose authentic superficial and partly intimate information, (iii) users tend to stay anonymous, (iv) disclosure is affected by factors like relationship, age, privacy, group size, and activity context	survey	126	[SMFM22]
2022	mitigating harassment in social VR	(i) highlights embodied harassment as emerging but understudied, (ii) marginalized groups are identified by avatar cues, (iii) users employ personal and platform strategies to mitigate harassment	interviews	30	[FZMA22]
2022	queer identity in social VR	social VR affords chances and limitations to act out and depict queer identity	interviews	29	[FA22]
2022	dancing culture in VRChat	dancing culture is driven by freedom, community, individual & shared experience, performance, self-expression and -exploration	interviews	17	[PHM22]
2022	phantom touch in social VR	a protocol that induced phantom touch sensations in 70% of participants	online survey & remote experiment with	20	[AY22]
2022	avatars of people with disabilities	users have (i) disclosure strategies like presenting a capable self and selective disability disclosure, and (ii) face certain challenges during avatar customization	platform review & interviews	19	[ZDLY+22]
2022	„mirror dwellers“ in social VR	the use of mirrors (i) contribute escapism, embodiment, (ii) causing conflicts between user groups on how to use them, and (iii) has internet cultural implications	social media posts analysis	-	[TB22]
2023	perceived presence & social support in social VR	self & social presence predict social support which associates with well-being	survey	1231	[vBAH23]
2023	maintain close ties in social VR	physicality, enhanced presence, and range of activities help maintain existing close relationships over distance	reddit post analysis	672	[ZF23]
2023	social support for LGBTQ+ users	social VR innovates online social support mechanisms for LGBTQ+ communities	interviews	29	[LFSA23]
2023	approaches to AI-based moderation for harassment mitigation	(i) users see challenges and limitations in AI-assisted moderation, (ii) they envision how users, moderators, and AI work together	interviews	39	[SLF+23]

the benefit of VR, i.e., perception of presence and embodiment, have adverse effects as they intensify harassment experiences or enable specific forms of online harassment like groping in the first place [BEEDS19, FZMA22]. And as users seem to have individual definitions of what constitutes harassment in social VR and personal strategies for mitigating those experiences, the

design of standardized platform policies and mitigation features is a significant challenge for developers and researchers [BEEDS19, FZMA22].

Nevertheless, recent insights indicate that social VR engagement has beneficial psychological outcomes associated with the perceived self, spatial, social presence, and social support in VR [BAH22, vBAH23].

However, as indicated in Table **2-2** and Table **2-3**, the above insights are primarily inferred from user interviews and online surveys and come with some methodological limitations to keep in mind. The findings revealed by interview studies are based on small samples due to their methodology. Therefore, they may offer very detailed perspectives on selected topics that do not readily apply to all social VR users. How representative these findings ultimately are and still be in the future cannot be conclusively assessed. Similarily, online surveys also have methodological limitations concerning representativeness. While their larger samples do allow generalizations to some degree, they still used biased convenience samples due to the limited access to social VR users over social media platforms like *reddit* and as platform owners do not share public information on the sociodemographics of their user bases [SGZM21, SMFM22, BAH22, vBAH23]. Furthermore, there is no knowledge about the causal relationships between user characteristics, platform features, social behavior, social experiences, and psychological outcomes [SGZM21, SMFM22, BAH22, vBAH23]. Therefore, it is also not yet possible to make definite assumptions about how attractive social VR applications, in their current form, will be for different social groups in the future.

In conclusion, although the literature already allows exciting insights into various selected and particular aspects of behavior and experience that current social VR users experience daily, the research area is still growing and provides many opportunities for further research. Thereby, researchers are challenged to validate the findings already obtained by finding new ways to collect data from more representative samples and applying more diverse data assessment and analysis methods.

2.3.3. Consumer Social VR Studies with Novice Users

In contrast to the preceding, the following section reviews studies that evaluate consumer social VR applications with samples of participants with no social VR experiences (see Table **2-4**).

One of the first studies to look at the user experience in consumer social VR of new users is from 2018 and evaluated small group behaviors and experiences in *Facebook spaces* over a longer period [MS18]. The focus of the study was how existing small group dynamics transfer into social VR. The evaluation found that emotional experiences in VR were very similar to those of f2f interactions, as existing group dynamics carried over into VR. In their conclusion, the authors pointed out that individual sub-aspects of their studied scenario have already been discussed and illuminated in previous research. Though, due to the new and, in the future broader access to VR technology, new research implications arise from their work that previous work did not cover [MS18]. As Table **2-4** indicates, several long-term studies were conducted over the last years, covering the following topics: changes in embodiment illusion over time [ONA+21], general adaptation processes of users over time during collaboration [KW21], team cohesion over time [THJ+22], social VR as an alternative to video calls [BRP+23], and effects of avatar and envi-

Table **2-4**.: Overview of studies where novice users engage in consumer social VR.

Year	Topic	Findings	Method	N	Reference
2018	longitudinal small group interactions	emotional experiences and interactions in social VR are similar to f2f	diaries & interviews	17	[MS18]
2019	photo sharing experiences in VR	photo sharing experiences in social VR assimilates f2f experience	lab-based user study & interviews & observation	26	[LKR+19]
2021	long-term use and embodiment illusion	regular use of an avatar increases illusion of virtual embodiment	remote user study in social VR	14	[ONA+21]
2021	proxemic behavior in VR	(i) proxemic behaviour in VR resembles in-person contexts, (ii) small and large spaces affect group formation and proxemic behavior differently	user behavior data logging during remote user study & interviews	26	[WLV+21]
2021	dating decisions in social VR	social VR allows users to take well informed decisions to meet or not meet in real life	qualitative lab-based user study	30	[YNR21]
2021	novice user adaptation in long-term collaboration experiences	users show adaptation processes to VR over time: (i) new ways to communicate in VR, (ii) emotion recognition ability increases	longitudinal lab-based user study, quantitative & interviews	20	[KW21]
2022	influence of environment design on social interactions	environment design affects early stages of social interaction during exploration	observation & interview	46	[CJL22]
2022	team cohesion and task collaboration in long-term social VR	primary affordances for team cohesion in social VR task collaboration are: (i) shared sense-making, focus, and workflows, and (ii) enhancing task & social relationships	interviews	20	[THJ+22]
2022	digital proxemics affected by audio and output technology	(i) background noise affects proxemic behavior in small groups, (ii) in VR, users keep more interpersonal distance and use more attention signals	user behavior data logging during remote user study	24	[WOGG+22]
2022	joint video watching in VR	joint video watching in social VR assimilates f2f experience	lab-based user study & interviews & observation	32	[MLC+22]
2023	long-term team meetings in social VR vs video calls	(i) users want to see others' faces, (ii) most users would stay with video calls, (iii) social VR can have advantages	qualitative & quantitative questionnaires	32	[BRP+23]
2023	effects of time, avatar & environment design	time, avatar appearance, and environment characteristics affect, i.a.: group cohesion, presence, realism, enjoyment, behavioral synchrony, and restoration	longitudinal field experiements	81 & 137	[HMD+23]

ronment design over time [HMD$^+$23]. In line with previous discussions [BY06], those studies indicate that user experience and behavior aspects may change as users become more familiar with the technology and adapt to specific affordances and limitations. Thus, over time the immersive experience, i.a., perceived presence, [KW21, HMD$^+$23], social presence [HMD$^+$23], and embodiment [ONA$^+$21, HMD$^+$23] may change. Further, user behavior and group dynamics may

change, e.g., as users adapt to limited affordances or social cues in VR, by finding new ways to communicate or getting used to recognizing others' affective states despite missing social cues [MS18, KW21]. Additionally, aspects relating to the avatar system [HMD+23], environment design [WLV+21, CJL22, HMD+23], task affordances [THJ+22], and audio design [WOGG+22] have also been identified to affect, i.a., immersive experience facets, group cohesion and building, proxemic behavior, and attentional signaling (refer to Table **2-4** for details and specific references).

Other user studies allow making assumptions about use cases consumer social VR applications could cover in the future. For example, social VR's interaction affordances seem sufficient for making well-informed dating decisions [YNR21]. Especially in cases where people cannot meet in person, initial studies show that social VR could be an alternative to the f2f variant or other technical solutions. For example, photo sharing and joint video-watching experiences in *Facebook Spaces* seem quite close to the f2f equivalents, even though the avatars used in the corresponding studies were criticized regarding limited graphical and behavioral realism [LKR+19, MLC+22]. Those critics reoccurred in a study that evaluated social VR as an alternative to video calls for conducting work group meetings. In particular, the lack of mimic tracking constituted a significant disadvantage of the used social VR platform [BRP+23].

The work presented in this section demonstrates, as a complement to studies of users that are already experienced with social VR, that long-term research is valuable for formulating informed assumptions about how users will experience social VR in the long term, and, therefore if and how they will incorporate it into their daily lives. They further demonstrate, complementing social VR design studies, that developers can influence aspects of the immersive and social experience through the purposeful design of avatars, the environment, and interactive affordances. Furthermore, assumably motivated by consequences of the Covid 19 pandemic, many of those studies indicate how social VR may be a sufficient alternative for in-person meetings and a superior alternative to existing communication technologies in the future, provided that VR technology continues to advance and overcomes the shortcomings identified in the studies.

2.3.4. Studies with Lab Prototypes Related to Social VR

This section provides a complementary perspective on consumer social VR applications by reviewing studies that evaluated custom prototypes in laboratory studies in the context of isolated questions related to social VR user experiences. Compared to the previous literature reviews on design, users, and studies with inexperienced users in consumer social VR, this review is least sharply defined in terms of separation from other areas such as general CVE, multiuser VR, or avatar research. Thus, the studies presented here do not constitute a comprehensive account of research activities in the given areas; for this purpose, an in-depth look at the individual publications and the research before 2018 cited therein is necessary. However, the publications listed in Table **2-5** and Table **2-6** suffice to situate our own two laboratory studies within a range of related literature and to close the loop between work that focuses on the final design of consumer applications with work focusing on isolated research questions in the broader context of multiuser VR that in turn inform application design.

Most of the work compiled in Table **2-5** and Table **2-6** can be attributed to studying the

Table **2-5**.: Overview (1) of studies with multiuser VR lab prototypes. Highlighted row belongs to this thesis' body of work.

Year	Topic	Findings	Method	N	Reference
2018	behavioral realism and social interaction	behavioral realism based on representation and avatar-control affects nonverbal communication	lab-based user study	102	[HOB18]
2018	communication behavior	immersive VR with user representations induces conversation patterns very similar to f2f interaction	lab-based user study	60	[SN18]
2019	graphic style of virtual humans	degree of realism of virtual human affects emotional responses of participants	lab-based user study	797	[ZMM19]
2019	social augmentation techniques	augmenting social interactions can alter aspects of user experience and behavior	literature & prototype review	-	[RBK+19]
2019	nonverbal synchrony with humanoid and abstract avatars	users showed natural nonverbal synchrony in VR, independent from avatar style	lab-based user study	192	[SSW19]
2020	personal space boundaries influencing factors	(i) personal space zones are consistent to real world, (ii) and can be modulated by object and others' avatar design	lab-based user study	40 & 40	[BPB20]
2020	avatar anthropomorphism	(i) various degrees of visual avatar anthropomorphism may not impact embodiment, (ii) but perceived attractiveness and (iii) task completion time	lab-based user study	36	[GDC+20]
2020	motion design of avatars	(i) perceiving avatar motion as attractive reduces accepted personal distance, (ii) men accept higher proximity than women	lab-based user study	20	[ZNO+20]
2020	collisions between avatars	(i) enabling collisions and providing feedback when avatars collide can intensify immersive experience (ii) collision design should depend on the interaction purpose of the application	lab-based user study	24	[RW20]
2020	emotional reaction to virtual social touch	virtual social touch (i) evoked various emotions and (ii) emotional reaction was modulated by touch intimacy, direction, and sex	lab-based user study	44	[SM20]
2021	immersive movie watching in multiuser VR	social VR introduces novel paradigms for co-watching experiences	user study & focus group	62	[LSJ+21]
2021	pre-social touch reactions in VR	distance-dependent pre-touch reactions affect avatar evaluation	lab-based user study	20 & 28	[MSK+21]
2021	hugging a virtual agent	tactile stimuli improve the hugging experience	lab-based user study	75	[CKM21]
2021	abstract vs. humanoid avatars and emotion recognition	with limited social cues anthropomorphism does not improve emotion recognition compared to an abstract user representation	lab-based user study	152	[SW21]
2021	gaze manipulation and social attention	gaze alteration positively affects group attention	lab-based user study	26	[RPM+21]

Table **2-6**.: Overview (2) of studies with multiuser VR lab prototypes. Highlighted row belongs to this thesis' body of work.

Year	Topic	Findings	Method	N	Reference
2021	video conference vs. multiuser VR	behavior patterns in VR resemble f2f more than patterns in videoconferencing	lab-based user study	210	[AKLN21]
2021	synthetic voice for virtual humans	synthetic voice vs. natural voice does not affect social presence and emotional evaluation of virtual human	lab-based user study	375	[ZCM21]
2021	influence of others' avatar	avatars that support subtle social cues contribute interpersonal communication	lab-based user study	36	[AI21]
2021	influence of self-representation and avatar consistency	the social effect of avatar consistency among users depend on their relationship	lab-based user study	17 & 18	[CWOGP21]
2021	influence of tracking fidelity	higher tracking fidelity for avatar animation leads to increased behavioral realism, social presence, and attractiveness	lab-based user study	40	[WWJ+21]
2021	reaction to virtual caresses	visual only touches in VR can induce realistic experiences as they are subjectively evaluated as physical touches	lab-based user study	42 & 42	[FLTA21]
2021	older adult interaction in multiuser VR	(i) reduced communication inhibition, (ii) highlighted importance of avatar customization depending on context, (iii) value of enabling connections over distance, (iv) need for behavioral realism	longitudinal lab-based user study	16	[BWC+21]
2021	social touch augmentation framework	(work in progress) visual augmentations of virtual social touch may intensify diverse facets of the immersive and social experience	focus groups with early prototypes	8	[SM21]
2022	self-disclosure via avatars in different media	(i) avatars without user-similarity encourage self-disclosure, (ii) avatars can lead to more self-disclosure than video chat	lab-based user study	108	[IIY+22]
2022	different virtual hand colors during virtual hand shake	warm hand color had positive effect on user experience compared to cold hand color	lab-based user study	25	[ISK+22]
2022	realistic vs cartoon avatars in mixed reality work meetings	designing avatar aesthetics for longitudinal acceptance differs from designing acceptable avatars	user study in work meeting context	14	[DWG+22]
2022	interpersonal distance to avatars and agents	rated attractiveness of agent models is negatively correlated with accepted interpersonal distance	lab-based user study	18	[ZNO+22]
2022	evaluation of and behavior towards realistic motion avatars	social interaction in VR can be very similar to f2f interaction in terms of enjoyment, understanding, self-disclosure, comfort, awkwardness	lab-based user study	52	[RBB+22]
2022	VR vs f2f compliance behavior	VR-mediated communication is as intricate as face to face	lab-based user study	46	[DKGS22]
2023	co-located video games in multiuser VR	player and social experience in VR closely matched f2f scenario	lab-based user study	50	[SKE+23]
2023	social touch augmentation	audio-visual augmentations evoke bodily sensations and support intimate bodily connection	prototype demonstrations	ca. 50	[DSSL+23]

influence of avatar design choices on various aspects of experience and behavior. A key area of research in this context is the degree of graphical or behavioral realism of avatars and how it affects non-verbal communication [HOB18, SSW19], affective responses [ZMM19, ZCM21], collaboration [GDC+20], emotion recognition [SW21], social presence [WWJ+21], and avatar acceptance over time [DWG+22]. Closely related are studies investigating behavioral responses to avatars, in this case, proxemic behavior [BPB20], and how factors like perceived avatar attractiveness affect it [ZNO+20, ZNO+22]. But also general questions regarding the type of user representation belong to this area, e.g., how different technological approaches to avatar generation support different social communication affordances [AI21, WWJ+21], or if representation (in)consistency among users affect their interaction [CWOGP21].

Another area of literature compares social interaction patterns in multiuser VR to other modes of interaction, like in-person scenarios or other communication technologies. Those studies evaluated general communication behavior [SN18, AKLN21, RBB+22], personal space zones [BPB20], self-disclosure [IIY+22], and compliance behavior [DKGS22] (see Table **2-5** and Table **2-6** for details).

Other studies share a focus on a specific type of embodied social interaction by investigating experiential aspects of virtual social touch, like the reaction to body contact of varying intimacy [SM20, FLTA21], pre-touch reactions [MSK+21], the role of haptic feedback when hugging a virtual human [CKM21], or the influence of transformed visual cues during virtual body contact [ISK+22, DSSL+23]. Related to this area is the question regarding general collision behavior between avatars that walk towards and into each other [RW20].

Some lab studies investigated potential use cases for social VR and implemented custom prototypes that would fit the individual experimental requirements to enable a controlled investigation of, e.g., experiences of watching an immersive movie [LSJ+21], the interaction of older adults [BWC+21], and simulating a co-located multiplayer game scenario in social VR [SKE+23].

In line with the case for designing experiences "beyond reality" that was mentioned in the social VR design literature [HS92, BBL+04, MSI21], four projects explored social VR's capabilities to affect social interaction by purposefully deviating from what f2f interaction offers [RBK+19, RPM+21, SM21, DSSL+23]. In particular, Roth et al. describe several approaches and classifications of social augmentations to alter social experiences by, e.g., manipulating virtual body posture and gaze behavior or introducing virtual artifacts that encode certain social behaviors and make them perceivable in novel forms (like particles that float between avatars that look at each other) [RBK+19].

In summary, the above studies indicate that interaction in social VR can resemble f2f interactions with regards to communication behavior and experiences [SN18, SSW19, BPB20, SM20, AKLN21, FLTA21, RBB+22, DKGS22, SKE+23], but also that design decisions on factors like the avatar aesthetics and their subtle social cues [HOB18, ZMM19, BPB20, ZNO+20, MSK+21, AI21, WWJ+21, SW21, DWG+22], and the behavior of other virtual objects surrounding virtual social interaction [RBK+19, RW20, ISK+22] shape experiential nuances. Further, insights on virtual social touch indicate that users show different affective reactions to virtual body contact depending on its intimacy, touch direction, and users' sex [SM20, FLTA21]. In this context, future advancements in haptic feedback technology may steadily increase perceived realism and assumably affective reactions of virtual body contact [CKM21].

This literature review complements the previous sections by highlighting that lab studies on isolated issues can aid the definition of practical implications for social VR design. Such implications could indicate what social dynamics from f2f interactions developers can expect to transfer to VR and suggest strategies to purposefully design application features to alter individual facets of user experience. In combination, those two types of implications empower developers to develop features that promote positive and limit negative behaviors and experiences. Thus, conducting controlled lab studies before making virtual social interactions available for the general public could eventually ensure that consumer social VR applications will be a venue for authentic, positive, and safe social interactions.

3. Body of Work

The previous chapter has covered the basics of immersive VR experiences and four areas of recent consumer social VR research. The following pages summarize the four publications that form the body of work of this dissertation. They include two studies from the area of everyday experiences of social VR users and two from multiuser VR laboratory studies with custom prototypes. Since the individual publications also stand on their own and are appended to this dissertation, this chapter just briefly reviews their individual motivation, research questions, applied methods, and relates their findings to the overall research question of the dissertation. For assessing the details on the experimental setups, the extensive results, as well as the topic-specific discussions, reading the publications themselves is of course required. The four studies offer the following four perspectives on this dissertation's overarching topic:

(i) The first study focuses on one of the fundamental and most intimate forms of social interaction: social touch. With a custom multiuser VR prototype, it unveils emotional reactions and moderating factors of virtual social touch.

(ii) The second study focuses on assessing what everyday value current consumer social VR applications have for users that use them regularly. Employing an international online survey, it unveils why and in what activities users engage in consumer social VR platforms.

(iii) The third study extends the perspective on daily user experiences. It provides insights into how users engage in one of the fundamental processes of socializing and relationship-building: self-disclosure. Again based on an international online survey among social VR users, it unveils what users disclose to each other and what factors moderate their self-disclosure behavior.

(iv) The fourth study evaluates if social VR is an alternative for popular leisure activities when in-person meetings are not feasible. Using an extensive user study with a custom multiuser VR prototype, it unveils the experiential differences and similarities of playing a multiplayer video game physically co-located compared to simulating this scenario in VR.

As each of the following publications is the culmination of successful collaborations with others, I will use the term "we", when describing them.

Study 1
The Experience of Social Touch in VR

This is the summary of the publication attached in section A.1 with the reference [SM20].

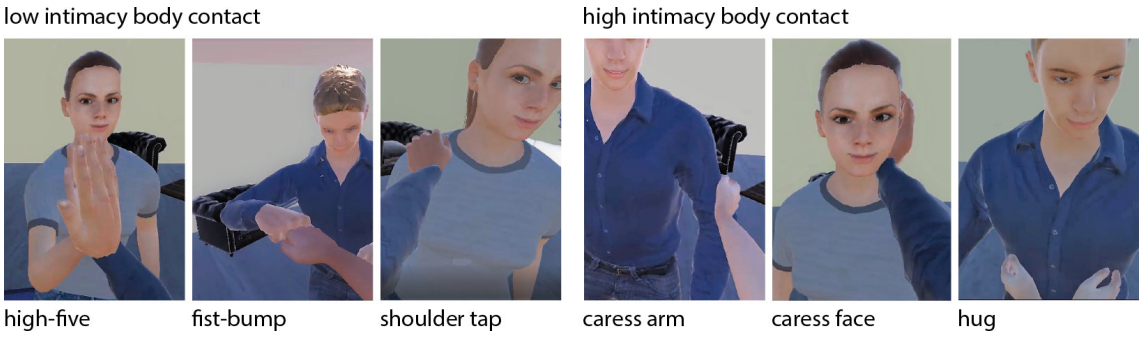

Figure **3-1.**: The different touch interactions participants performed in our study. Illustration taken from [SM20]

As outlined in chapter 2, multiuser VR enables users to perceive spatial proximity and distance to each others' virtual representations in a way that other, less immersive technologies do not allow. And the way modern VR headsets and tracking technologies integrate input and output data streams with this virtual space makes one of the most intimate forms of interpersonal communication naturally executable and perceptible in VR: social touch [JY85, Fie02, SNKI13]. Designers of consumer social VR applications already utilize virtual body contact as engaging social features (e.g., a handshake for friending in *RecRoom*). Unfortunately, there also seems to be a dark side to transferring social touch into VR, as virtual forms of physical harassment are already reported by researchers [BEEDS19] and motivated platform developers to integrate safety features that, to some degree, prevent social interaction between avatars at all (e.g., personal space bubbles). Given that modern VR is, in particular, a visual medium, we assumed that the above mentioned positive and negative aspects related to virtual social touch heavily depend on what users see in VR, contrasting the haptic nature of body contact in unmediated interaction. In line with our assumption, research on cross-modal sensory interactions indicates that perceiving only visual cues of social touch can induce reactions similar to actually being touched [BBB$^+$05, MRBM08, BO11]. Thus, researchers and developers of social VR experiences should be motivated to understand the user experience and its determinants related to virtual social body contact. However, when preparing the study presented here, we have identified a gap in research regarding the assessment of emotional responses to social touch in multiuser VR scenarios. Studies that investigated virtual social touch have either not been interested in emotional reactions [BY08, BSM$^+$13, TRVC$^+$16, HSA$^+$17, ZHvdV17, SP19], or deviated significantly from the fidelity of consumer social VR application by not utilizing virtual user representations [SP19, HRN$^+$20], heavily restricting users' body movement [FLTA21] or not employing an actual multiuser scenario [FLTA21]. Thus, as users worldwide could already engage freely in virtual social touch interactions, we wanted to contribute to the domain systematic insights into how users experience one of the most intimate forms of human interactions in VR. We thus set out to answer the following research questions by conducting a user study with a custom multiuser VR application:

Q1.1 Does virtual social body contact evoke emotional reactions?

Q1.2 What factors shape the emotional response to virtual social body contact?

Method

Our research questions required us to implement a VR application that allows users to touch each others' avatars while we could control the literature-based influencing factors touch intimacy, touch direction, and user sex. We implemented a custom multiuser VR application and conducted a controlled lab study that required two users to perform various social touches in VR Figure **3-1**. In contrast to related work, we employed full-body avatars and tracking, allowing users to move freely and control their avatars within the virtual environment. In the study, participants believed they would interact with another remote participant, while the other participants was a research assistant in another room. The participants and the assistant could not speak with each other during the interaction to rule out the influence of verbal communication. To control the effect of participant sex, the research assistant embodied an avatar of the opposite sex. The application prompted the participant and the assistant to initiate and receive a series of different touches (controlling touch direction), with each touch either being a high-intimacy touch (e.g., hug), or a low-intimacy touch (e.g., high-five) (controlling touch intimacy) Figure **3-1**.

In a within-design study, we eventually assessed the immersive experience in terms of presence, social presence, and embodiment and the emotional reactions based on perceived happiness, relaxation, desire, anxiety, disgust, and fear of 44 participants. We further assessed the individual comfort with social touch before the virtual interaction.

The data analysis comprised the description and visualization of participants' emotional reactions and inferential analysis of the main and interaction effects of the potential influencing factors on the individually assessed emotions. We further evaluated the association between individual comfort with interpersonal touch and the emotional reaction to virtual social touch.

Findings

F1.1 Participants reported positive and negative emotional reactions to virtual body contact. Thereby, the reported intensity of the emotional response varied among individuals.

F1.2 Moreover, our inferential analysis revealed that the affective reaction was affected by the main and interaction effects of factors known to modulate unmediated social touch, i.e., intimacy, participants' sex and the direction of touch. Further, positive emotional responses positively correlated with the individual comfort with interpersonal touch.

Figure **3-2** illustrates the self-reported emotional reactions of participants represented by emotions with positive and negative valence.

Virtual body contact elicited emotional responses of varying intensity and valence. Thus, our work, complementing similar work with yet different technical setups [FLTA21], highlights that virtual social body contact shapes the user experience of virtual social interaction, even if users primarily perceive it by visual and not haptic stimuli. Further, our findings indicate that the experience of virtual body contact, similar to unmediated social touch [HNN83, Tom08, SNH+19], is not easily predictable and depends on the specific social context determined by factors like touch intimacy, touch direction, and user sex. Thereby, aligning with user reports of virtual physical harassment [BBB+05, FZMA22] and related lab studies [FLTA21], our results indicate that the concept of intimacy, and its violation based on body contact, applies to virtual interactions. We admit that the identified effects are small. However, given that participants had no reason for being emotionally involved in the prescribed social interaction with limited

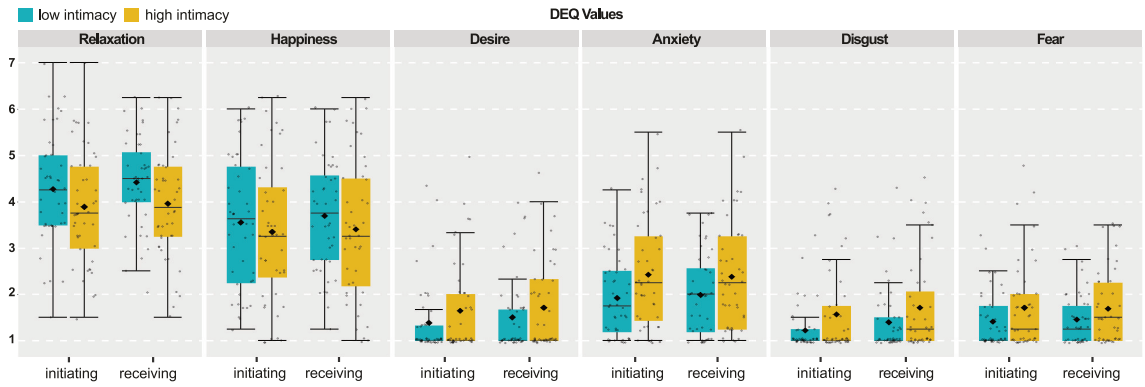

Figure **3-2.**: Boxplots illustrating individual, mean, and median data of emotional reactions to different types of virtual body contact. Illustration taken from [SM20]

communication channels, it is notable that it still elicited emotional reactions that were affected by specific context factors. Assuming that users of consumer social VR applications are intrinsically motivated to interact with other users and maintain various relationships with each other, virtual social touches should play an even more significant emotional role in everyday social VR experiences than the results of our study suggest at first glance. We see this assumption validated by the infamous insights into virtual harassment [BEEDS19, FZMA22].

Concerning the overarching research question of this dissertation, these findings illustrate that performing one of the most intimate forms of social interaction in VR can evoke emotional responses even if presented with limited sensory fidelity. Thereby, factors known to affect the experience of physical social body contact also shape individual user experiences in VR. Thus, in terms of the sociality of social VR we consider these results as indicating a resemblance to f2f interaction. Further, as this type of embodied user interaction is exclusive to VR, our results highlight VR as having the potential to stand out as a social platform with unique social experiences compared to other media. However, this uniqueness comes with the positive and negative implications of transferring such a fundamental type of social interaction into VR. Eventually, given the technological advances we can expect in the coming years, our study results are likely only a hint of the significance that virtual social touch will have in tomorrow's social VR applications.

Study 2
User Activities & Motives in Consumer Social VR

This is the summary of the publication attached in section A.2 with the reference [SGZM21].

A few years after Mark Zuckerberg's statement that VR would be the "most social platform ever," today's consumer social VR applications allow us to evaluate this assumption based on real-world user experiences. In this context, the study presented in this section was motivated by two fundamental questions: (i) What are people doing in consumer social VR, and (ii) why are they using it?

When we prepared the study presented here, another research team published a series of qualitative analyses on consumer social VR experiences in different contexts: long-distance relationships, anonymity, cross-generational interaction, non-verbal communication, and avatars [ZF19, MZF20, MFW20, FM21, MFR20]. While all these studies provided exciting initial insights into particular aspects of social VR user experiences, they did skip the more fundamental questions we set out to answer. However, one of those interview studies (published as we wrote our paper) took a more general look and asked users what makes social VR engagement meaningful for them without focusing on a specific context [MF20]. Based on in-depth interviews with 30 social VR users, this study provided excitingly detailed yet very personal initial insights into the driving factors of social VR engagement. However, due to the qualitative approach, those results do not allow general conclusions about what most users may value about social VR. In contrast, we designed our study to assess a more extensive data set by asking more social VR users to eventually be able to infer more general conclusions about the prevalent motivations to use social VR applications. Specifically, we set out to answer the following research questions:

Q2.1 What are users doing in their favorite social VR applications?

Q2.2 What are the motives that drive their social VR usage?

Q2.3 What makes social VR superior to other digital social places?

Q2.4 What do users want to be improved in the future?

Method

Aligning with our goal to assess data from a larger sample, we opted to conduct a standardized survey study among social VR users. We applied the Uses and Gratifications Theory (UGT) as a theoretical framework for crafting the survey. This theory originates in the 1940s in the context of empirical mass communication research and aims to identify media usage motives [BK74]. This theory's particularity is the assumption of active and self-reflective media users, which, due to personal needs, consciously control their media usage behaviors and aim to use those media that they expect to meet their needs [KHG73, BK74]. The theory is an established, evolving approach for understanding media use [Rug00] in diverse technological contexts. It is typical for studies that apply UGT to either re-use previously identified categories (e.g., [HB14, SH17, PKAH20]), or to use open-ended questions for exploratory analysis to identify novel types of needs and user motivations for specific media contexts (e.g., [ZJV+11, HB14, PKAH20]).

Considering the novelty of today's social VR applications, we opted for the latter and applied a strategy of open-ended questions that participants would answer using freely articulated text input. Basically, we asked users to indicate their thoughts on the questions defined above. In addition, we have included the User Motivation Inventory (UMI) [BVOM18] to determine the degree of motivation internalization of the participants, i.a. if their engagement in social VR is motivated by extrinsic or intrinsic motivation and whether they are likely to continue to use it. Eventually, users were asked to determine the perceived social closeness in social VR based on additional custom items.

Eventually, we shared the survey among social VR users using the online platform *Reddit*[1], that provides direct access to user communities of consumer social VR platforms. Overall, 273 persons participated in the online survey.

Data analysis mainly comprised an iterative content analysis of the free-text answers. This process required (i) the initial categorization of free-text answers using literature-based category codes, (ii) the definition of additional codes for new categories, (iii) the discussion of the resulting answer categorization, and eventually (iv) finding an agreement on a final categorization.

Findings

F2.1 Most participants use social VR to socialize and entertain.

F2.2 Correspondingly, the most prevalent motives we identified were related to social benefits, followed by experiential qualities, personal well-being, and functional benefits.

F2.3 Social VR can provide access to social experiences that some participants reported they do not experience elsewhere due to VR's immersive qualities that contribute to expressiveness and an authentic social experience.

F2.4 However, participants want social VR to be even more immersive and improved in terms of social interaction and basic user experience.

The above insights are inferred from Figure **3-3** that illustrates all categories and respective occurrences that we identified during content analysis.

Our results provide insights into the "why" and "what" of social VR user engagement. Although limited in terms of the applicability to social VR users and applications in general, the study contributes to the field by providing a coherent framing for topics that other investigations in the field can apply to deal with individual topics in more detail. Further, the results allow an estimation of the relative importance of the identified categories based on the quantitative presentation, a contribution previous studies did not offer. Furthermore, our study is the first to opt for a large sample by utilizing an international survey study to identify larger patterns among social VR users. This approach naturally extends related interview-based studies in terms of methodology and findings and was also utilized by later studies that in turn extend our initial findings by linking user behavior to psychological benefits [BAH22, vBAH23].

Regarding our leading question if VR is the most social platform this study is of course only a snapshot of the users and individual social VR applications surveyed in its context. However the results offer an idea of the everyday value that future users of social VR applications could also have. In this respect, it remains to be seen at what pace the technology will actually advance and be accepted and used by more and more people, as well as the question of the factors influencing this dissemination process. Furthermore, it remains to be seen whether people who do not use VR today will see an equal benefit in social VR once they have access to it. Nevertheless, our findings indicate the real-world benefits today's social VR users already derive from these applications in their everyday life and that social aspects are a driving factor for

[1]Reddit, last accessed February 26th, 2023: `https://www.reddit.com`

Figure **3-3**.: Sample overview and derived user activities, motives, perceived benefits and wanted features of social VR users. Illustration taken from [SGZM21] ©2021 IEEE

them to engage in social VR. Thus, this study aligns with related work and shows that social VR can be a venue for meaningful social activities where users satisfy social (and other) needs in ways they do not find in other digital social worlds.

Study 3
Self-disclosure in Consumer Social VR

This is the summary of the publication attached in section A.3 with the reference [SMFM22].

As unveiled on the previous pages, socializing is what many users seek and do in social VR. They socialize by having conversations in hangouts or intimate get-togethers and being motivated by meeting people to establish and maintain interpersonal relationships. Thus, conversations are a significant part of the user experience in social VR. Conversations are a fundamental driver for getting to know other persons as they are a means to disclose or reveal personal information to each other. And disclosing personal information to others forms the foundation for strong social connections with acquaintances, friends, and loved ones [AT73, Sto87, KD02]. Against this background, the study presented here is again motivated by fundamental questions: What are people talking about in social VR? Do they engage in meaningful and personal conversations, or do they engage more in superficial small talk?

Specifically, we wanted to extend a previous study that initially investigated aspects of self-disclosure in social VR using qualitative user interviews [MZF20]. These initial results have shown that users feel comfortable disclosing emotional and personal information in social VR [MZF20] but did not further specify what exactly people are disclosing to each other on a broader scale. Additionally, the study found that users perceive a trade-off between enjoying the natural ways of self-disclosure (via voice or body language) and concerns about privacy risks implicitly embedded in the technology due to the natural interaction affordances [MZF20]. However, the study did not indicate if many users feel this tension and if privacy is thus a permanent and ubiquitous concern during self-disclosure. For example, do users have general tendencies to disclose certain information in specific contexts and avoid disclosing it in other contexts? Analogous to the study of user motives (chapter 3), our take on self-disclosure in social VR aimed to extend previously gained insights by identifying more general patterns of user opinion by assessing data from a larger sample using an international online survey. Specifically, we set out to answer the following research questions:

Q3.1 What do users think about disclosing to others in social VR?

Q3.2 What topics do they disclose?

Q3.3 What goals drive their self-disclosure behavior?

Q3.4 What contextual factors influence their disclosure decisions?

Q3.5 What technical channels do they use to disclose to others?

Method

Based on our experiences with the survey study on social VR user motives, we again conducted an online survey with many participants to identify patterns of opinion and behavior among many users. However, as this survey was intended to cover many areas of self-disclosure and the interplay of certain factors, we mainly applied closed-ended questions that would allow us to conduct a more streamlined analysis compared to the qualitative approach we used in the previous study. We applied the Social Penetration

Theory as a theoretical framework for deciding the topic categories to include in the survey [AT73, CG15]. This theory describes an archetypal progression of interpersonal relationship-building that is interdependent with the types of information that people disclose to each other. It states that information of different intimacy levels is shared in different stages of relationship development. Thus, one discusses rather superficial topics with strangers and the most intimate topics with romantic partners. Accordingly, by sharing more and more personal information, the relationship develops further, which in turn leads to more personal information being shared. So, looking at the topics users talk about in social VR should allow to some degree, to infer their relationships. Eventually, we asked participants to indicate if they disclose information from the following topics, ranging from lower to higher degrees of intimacy according to Social Penetration Theory: lifestyle preferences, goals and aspirations, religious and political convictions, fears and fantasies, and their concept of self. Additionally, we asked them to indicate if they would disclose information about their true identity and sexuality, as previous studies dealt with those particular topics in social VR [MZF20, AF21]. To unveil if users tend to disclose the above information types in specific contexts, we included several factors in the study that are known to affect self-disclosure in general and reflect specific social VR features previously discussed in the literature: relationship type, privacy, age, group size, and activity context. For each context factor in general and specific example contexts reflecting those factors, participants were asked to indicate if they would disclose a particular information type in this context. Further, we asked users about their self-disclosure motivation based on custom items derived from literature on the functional approach to self-disclosure [Oma00]. Furthermore, participants were invited to openly indicate what technical channels they use to disclose personal information to identify chances for novel types of self-disclosure that social VR may offer compared to other communication technologies.

Eventually, we shared the survey with social VR users via several subreddits dedicated to social VR and received 126 valid responses that entered the mainly descriptive analysis. We opted for a visual illustration of the data that would allow the assessment of opinion distribution among participants and the identification of self-disclosure patterns based on the answer patterns in the survey.

Findings

F3.1 Our results show that many participants see social VR as a way to make authentic connections, despite skepticism and privacy concerns considering self-disclosure.

F3.2 Users tend to disclose information related to sexuality, lifestyle, and personal goals but are less likely to share information that would reveal their true identity or are highly intimate.

F3.3 While serving different functions, relational development and identity clarification seem to be most important for most social VR users.

F3.4 Factors such as the relationship to the persons they are disclosing to, their age, privacy factors, the group context, and activity context influence self-disclosure decisions in social VR. Further, the context factors affect the self-disclosure decisions of some participants in patterns observable in f2f interaction.

F3.5 Self-disclosure happens mainly verbally through conversation, but user avatars, user profiles, the environment, external apps, and specific media are also used for self-disclosure.

Figure **3-4** exemplifies how we approached data analysis and presentation by illustrating the results considering users' tendencies to disclose certain types of information in specific contexts. Generally speaking, predominantly blueish columns in the heatmap indicate disclosure-promoting contexts, whereas red columns indicate disclosure-inhibiting contexts. Yellow columns represent contexts with no clear pat-

Figure **3-4.**: Heatmap illustrating that self-disclosure decision tendencies differ based on information type and social context. Illustration taken from [SMFM22]

terns.

Our findings contribute to social VR research by extending previous insights as they foster a comprehensive understanding of how factors like relationship, anonymity, and other contextual factors affect the disclosure of certain types of information and for how many people those factors are relevant. Further, our study provides the first insight into what specific topics social VR users disclose to others. Eventually, we provide the first theory-based assessment of what specific functions self-disclosure in social VR fullfills, whereby those goals align with the previously identified motives that drive social VR engagement [SGZM21] as well as other benefits of social VR like identity exploration through avatar customization [FM21].

Based on our findings, social VR seems to offer opportunities to engage in authentic, natural conversations, where self-disclosure aids relationship-building and identity clarification. Although users disclose diverse topics, more than half of our participants stated that they do not discuss more intimate topics with others. Further, for many users, disclosure depends on specific contextual factors, i.a., factors that influence self-disclosure decisions in f2f interactions. Specifically, some users show patterns of disclosure decisions that reflect f2f interactions, where disclosure of private information tends to happen within dyadic boundaries and safe environments. Thus, concerning our guiding question, we see our results indicating a certain naturalness inherent to conversations in social VR, as in f2f conversations, people typically also do not reveal every intimate detail independent of the social context.

Study 4
Simulating Co-located Videogames in Social VR

This is the summary of the publication attached in section A.4 with the reference [SKE+23].

Figure **3-5.**: Impression of the VR application we developed for the controlled lab study. Illustration taken from [SKE+23]

As described in chapter 2, the immersive characteristics of VR allow us to experience a shared three-dimensional reference space that resembles the spatial context of f2f interaction. The study on virtual social touch showcased that we can naturally replicate certain types of interaction in this space. However, as VR is a highly immersive medium, it can also simulate other types of media [Sla09] and thus can replicate whole social activity contexts where users interact using those media, like sharing photos or watching movies together [LKR+19, MLC+22]. As during the Covid 19 pandemic in-person social activities were only feasible in limited ways, the study presented in this chapter was motivated to find out to what extent current consumer-grade VR hardware and software can replicate a popular social leisure activity that involves the interaction through another type of medium with all its experiential qualities.

As such a popular activity, we identified the co-located playing of digital multiplayer games. While modern online multiplayer games allow time- and place-independent scheduling of game sessions with others [VKJ+16], many players still enjoy coming together physically and playing co-located, or local digital multiplayer games regularly[2]. A reason for its remaining popularity lies in the unique experiential qualities that characterize local multiplayer, e.g., giving a high-five and seeing the others' facial expressions [SPM11, KQ14], which result in additional sociability that online games often can not offer. As VR

[2]Entertainment Software Association - 2021 Gaming Industry Facts, last accessed February 28th, 2023:`https://www.theesa.com/resource/2021-essential-facts-about-the-video-game-industry/`

generates a shared spatial reference space in which those interactions can take place, we set out to explore to what degree the sociability of co-located play transfers to VR. Adding up to a sparse literature landscape on replicating joint media consumption scenarios in VR, we designed and conducted a user study comparing the experiential qualities of playing a digital multiplayer game physically co-located with playing the same game within a social VR environment while being physically separated. The following two research questions guided our work:

Q4.1 How do the player and social experience in VR compare to the experience in the f2f setting?

Q4.2 What features enhance or inhibit the player and social experience in VR?

Method

We developed a VR application that allows two players, represented by customized, stylized avatars, to meet and play a multiplayer game in a virtual replica of one of our laboratories (Figure **3-5**). In this virtual lab, the players see the game on a virtual model of a 50-inch TV screen while sitting together on a virtual sofa. While using the VR app, the players are in two different but same-layout rooms, where they sit on the physical version of the virtual sofa. Based on our positive experiences with shared control as an engaging social game mechanic, we reused a game we developed for a previous study [SEM18]. This shared control game requires players to simultaneously control the same player object to proceed in the game. Given its simplicity in aesthetics, level design, and control scheme, this game would work equally well in VR and f2f in terms of inducing social interaction. Further, it met several design requirements we defined for our study design: (i) it is easy to implement and performs well, (ii) it is easy to understand, (iii) it induces social interaction by making players interdependent, and (iv) it is engaging. Thus, we developed the shared control game in two versions: one to run on a desktop PC and a physical TV monitor and a version for our VR app to run within the virtual environment on a virtual monitor.

Eventually, we compared the two versions, co-located and VR, in a within-design user study by collecting quantitative, questionnaire data and qualitative data based on recordings and semi-structured interviews from 25 pairs of participants. The questionnaire data would unveil the player experience (e.g., enjoyment) and the social experience (e.g., social presence). The recordings and interviews would reveal details about social behavior and how specific aspects of the two conditions may have affected it. Further, the interviews aimed to assess users' general opinion on using VR in such a way privately.

Correspondingly, the data analysis comprised quantitative and qualitative methods. The quantitative data were analyzed using frequentist statistics to compare central tendency measures of questionnaire subscale data. The qualitative analysis included video analysis (i.e., counting specific behavior types and describing social interactions) and a thematic analysis of the interviews [BC19, BC21].

Findings

F4.1 Players had a similar player and social experience in both conditions, with statistically significant yet practically marginal differences regarding individual experiential aspects. The VR version induced a slightly less rich experience and less co-presence, mutual attention and understanding, and affective understanding. Still, both versions caused an increase in social connectedness between players.

F4.2 While the observations and interviews identified the lack of facial animations, limited body language, and a low field of view as VR's main inhibiting aspects, the virtual experience benefited from interaction during the three-minute game break, avatar customization and its novelty character for novice users. The identified inhibitors are closely tied to technical limitations, which future

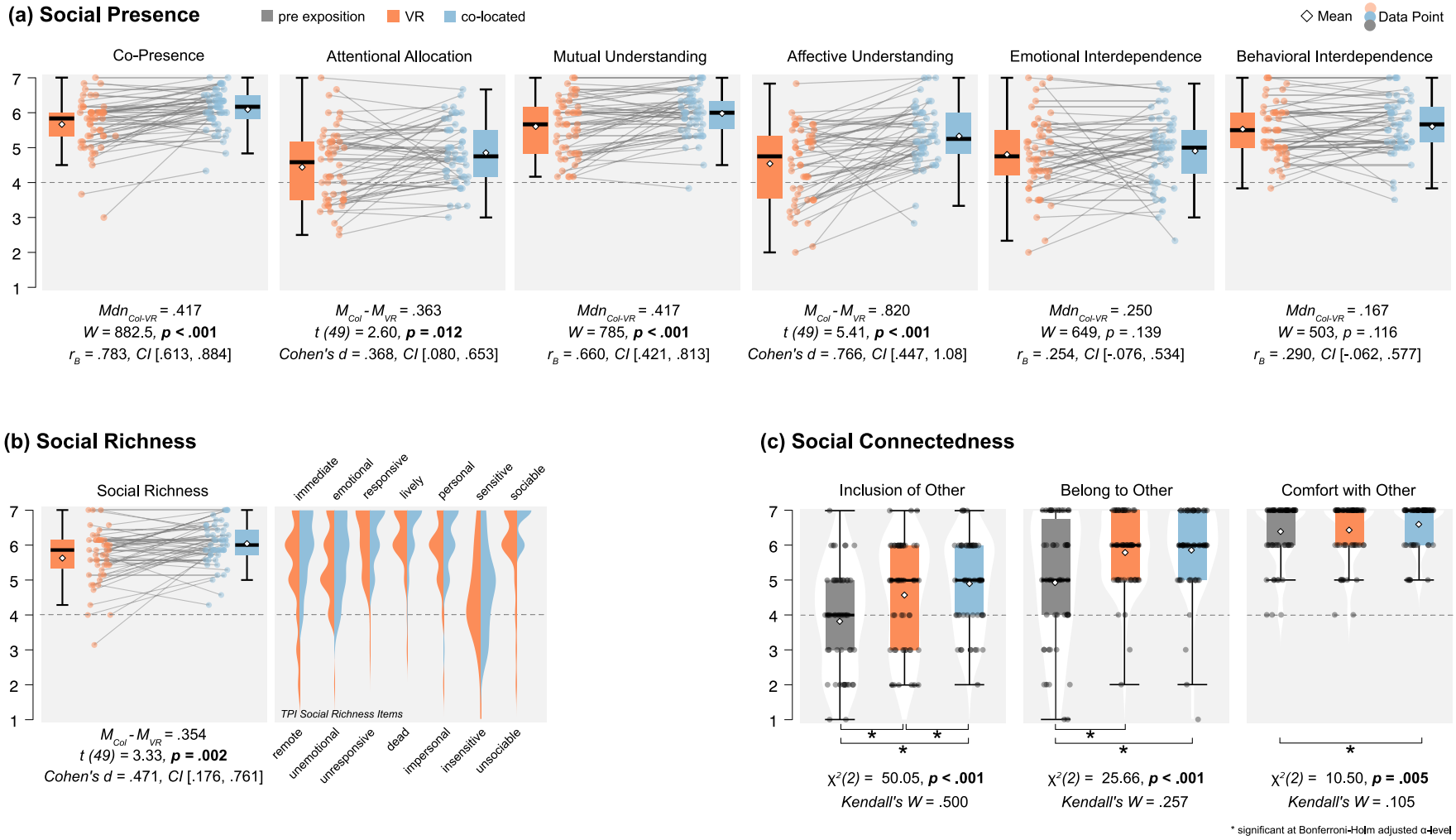

Figure **3-6.**: Boxplots illustrating how similar the social experience of co-located multiplayer gaming is in VR and in-person. Illustration taken from [SKE+23]

consumer VR devices will certainly overcome. The spatial orientation of the players to each other, induced by focusing the virtual monitor, has both positive and negative effects due to the technical limitations of the VR hardware.

Figure **3-6** summarizes the quantitative results comparing the social experience between the two conditions based on three experiential qualities: (i) social presence, i.e., a sense of co-presence and engagement between users [BHG01], (ii) social richness, i.e., the perceived "warmth" of the interaction [LDW09], and (iii) social connectedness as a transformative social outcome. Those three perspectives provide a comprehensive assessment of the social experience that extends insights of related studies on joint video watching and photo sharing in VR [LKR+19, MLC+22].

Our findings align with previous work that also found the VR replicas of joint media consumption scenarios providing slightly limited social experiences compared to f2f [LKR+19, MLC+22]. Further, our results extend those previous findings by providing a more nuanced assessment of the experiential dimensions and thus enable a more nuanced discussion of how certain context factors inherent to the scenario and technology affect individual experiential facets. From a broader perspective, our findings regarding positive social outcomes, i.e., increased social connectedness, align with social VR literature describing the benefits that users already derive from consumer social VR platforms [PS17, MF20, SGZM21, BAH22]. Further, we found many participants were open-minded about using social VR in their leisure time due to its specific advantages compared to other media. Specifically, our qualitative analyses highlight that next to the activity context, VR-exclusive features, like avatar customization, create opportunities for social interaction that does not occur in f2f interaction, justifying the call for sociality in VR beyond reality [MSI21].

Relating our findings to the overarching question of this dissertation, we consider current consumer-grade social VR technology as sufficient to replicate popular social leisure activities and experiences where specifics of the activity context compensate for the current technical limitations of VR. In particular, we interpret the identified experiential differences as practically marginal in real-world use cases where f2f interaction is not feasible and thus can not be directly compared to the VR replica. In those cases, we assume that users are satisfied with the overall experience, despite a direct comparison would highlight experiential limitations. Further, as consumers now have access to improved VR headsets with integrated face and eye tracking, one of the main limitations we identified will be practically insignificant once those new devices are widespread among users. Of course, our study comes with specific limitations discussed in the paper. Still, overall, our study results are a supporting indicator for consumer social VR's potential for being a social platform that offers users exclusive benefits in specific use cases where non-immersive social technologies can not deliver the same experience.

4. Discussion

The synopsis of this dissertation concludes with a discussion of the guiding question, taking into account the results from publications 1-4. These are summarized again at the beginning and are related to each other. Subsequently, the guiding question is answered based on the study results. This chapter ends with a discussion of this dissertation's limitations and the identification of important fields of further research in the context of social VR.

4.1. Main Findings

Study 1: What is the experiential quality of virtual social touch?
Our findings indicate that virtual body contact elicits emotional responses and thus transfers a fundamental form of social interaction into VR. Moreover, factors known to modulate social touch responses in f2f interaction, particularly intimacy and sex, modulate the affective reaction in VR. Furthermore, the individual comfort with interpersonal touch positively correlates with the intensity of positive responses to virtual social touch.

Study 2: Why do people use consumer social VR applications?
Our findings indicate that current consumer social VR applications are in particular venues for social interactions and satisfy social user needs. In this respect, social VR seems to give access to social experiences that many users tend not to experience on other digital social platforms or even the real world due to the immersive affordances of VR.

Study 3: How do social VR users engage in self-disclosure?
Our findings indicate that social VR provides access to authentic connections with others through self-disclosure. Although users tend to control the disclosure of anonymity-breaking information, such as real names and topics associated with more intimate aspects of oneself, diverse topics of varying degrees of intimacy are discussed in social VR. Thereby, self-disclosure benefits, i.a., relational development, and identity clarification, and depends on contextual factors like the relationship between users, the privacy of a virtual environment, or the activity context. Resembling f2f contexts, self-disclosure of more personal information seems more likely within controllable boundaries, like dyads and private contexts.

Study 4: Can social VR replicate the experiential qualities of a popular in-person social leisure activity?
Our findings indicate that current state-of-the-art social VR applications can provide a sufficient alternative to in-person leisure activities in cases where in-person meetings are not feasible. Although negatively affected by the technical limitations of current VR headsets, the virtual version of a popular leisure activity closely approximated the experiential qualities of its f2f counterpart, providing a rich social atmosphere and strengthening social closeness.

Each of the four studies included in this dissertation also stands on its own and is discussed individually in the respective publication. Here, an overall picture of how they relate to each other is sketched out. For this purpose, Figure **4-1** illustrates the thematic connections between the four studies by relating Studies 1, 3, and 4 to certain social VR users' activities, motives, perceived benefits, and wanted features unveiled in Study 2. Study 2 is the reference point for the other studies as it offers a comprehensive perspective on how real-world users use consumer social VR applications. The other studies, however, complement this overall perspective by providing deeper insights or illustrative examples for certain experiential qualities identified in Study 2. In the following, the connections between the studies are discussed.

A Touching Experience

Study 1, which explored emotional reactions to virtual social touch, is thematically associated with all four thematic areas of Study 2, i.e., social VR users' activities, motives, perceived benefits, and wanted features. The realistic (visual) simulation of body contact in VR is a particular example of how sensory immersion and the illusions of place and social presence enable the mediation of intimate social interaction at a distance. Thus, social body contact is an illustrative example of the immersive and social benefits users see in consumer social VR in the form of increased expressiveness and interactivity and more meaningful interactions with others compared to media that do not offer the same degree of immersion and social experience [SGZM21].

Concerning the activities in which many social VR users engage [SGZM21], virtual social touch relates, in particular, to intimate get-togethers as Study 1 [SM20], and related work [FLTA21] showcase that the intimacy associated with the body zones that are involved in virtual social touch affect user responses to it. Virtual social touch is thus a means to express intimacy in VR and enables users to express themselves in ways that correspond to the intimacy of their relationship, like romantic partners holding hands [ZF19]. Thus, being able to touch others and being touched by others certainly contributes to intimate encounters and general relationship-building in consumer social VR, with the latter also indicated in related work [FA21]. In this regard, Study 1 further relates to the user motive of establishing meaningful relationships. Additionally, being able to simulate body contact also addresses the need for substituting specific social experiences that people may not be able to experience outside of VR, i.a., couples in long-distance relationships that seek embodied experiences over distance [ZF19].

Notably, we consider users' desire for added security and safety features [SGZM21], e.g., in light of virtual harassment in consumer social VR applications [BEEDS19, FZMA22], as an implication to taking a critical perspective and finding ways to prevent abusive behavior and offer mitigation strategies to limit adverse social outcomes of virtual social touch. Virtual social touch further relates to other areas that users want to see improved. Better and more extensive tracking technologies would contribute to the precise execution of body contact and determines what body zones users can touch. More extensive sensory immersion, e.g., adding realistic haptic feedback, would probably intensify the experience [SGZM21, ISK+22].

Taking into account the effects of purely visual touch [SM20, FLTA21, AY22] and the anticipated and desired progress in the development of haptic feedback devices [CKM21, vHHTvE22], social touch presumably will be a significant contributor to social experiences, in particular intimate experiences, in VR in the future, just as it is in unmediated communication. Correspondingly, to do justice to the role that touch plays in human development and well-being, there are calls from researchers and developers to design and pursue a comprehensive agenda regarding the risks and opportunities when transferring social touch into the virtual realm [JPS+21].

Let's Get Personal

Like body contact, self-disclosure relates to all four themes of Study 2. As it is a predominantly verbal process, it mainly refers to the popular consumer social VR activity of having conversations and those that inherently include a conversational aspect, like intimate get-togethers. In this regard, the insights on self-disclosure from Study 3 allow more detailed descriptions of how conversations happen in social VR,

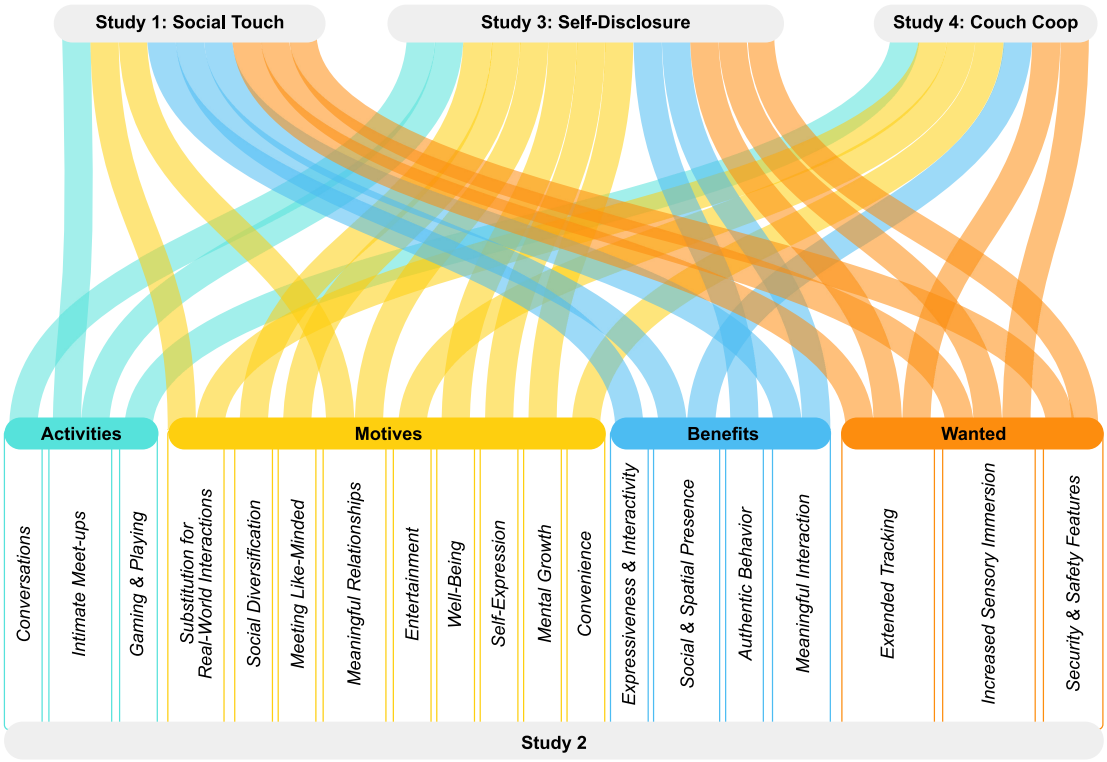

Figure **4-1.**: An illustration of the thematic connections between the four studies of this dissertation.

i.e., conversation topics, social contexts, and goals. For example, the findings regarding how some users follow specific patterns to decide for or against disclosing superficial or personal information reveal that intimate meetups between users are more likely to happen in dyadic contexts and between users with a friend-like relationship within private virtual environments and not in public spaces [SMFM22].

The results of Study 3 also allow assumptions of how users pursue motives that require users to share information, like leaving one's social bubble, finding like-minded people, or establishing meaningful relationships. Assuming those goals motivate people to disclose information of varying intimacy to other users, the insights gained in Study 3 allow assumptions about the social contexts users require to address their social needs [SMFM22]. But also self-related motives and needs, like supporting one's well-being, self-expression, and mental growth, are linked to self-disclosure, as in particular indicated by the self-disclosure goals that users pursue, i.e., getting accepted and liked by others, relieving distress, getting closer to others, understanding oneself [SMFM22].

While not being a direct indicator, the instance that users authentically disclose to others [SMFM22] presumably contributes to the overall perceived benefit of consumer social VR, that users perceive the social interaction in there as more authentic and meaningful than in other digital social places [SGZM21]. The increased authenticity seems also linked to VR's immersive features, like its capability to complement verbal communication with nonverbal social stimuli like gestures, postures, or social touch [MFW20].

Like social touch, self-disclosure will benefit from features that users want to see improved. Especially the tracking of eyes and mimics will probably contribute to self-disclosure authenticity based on the combination of verbal and nonverbal stimuli and the added channel to disclose, e.g., affective states [MFW20]. But again, as indicated by users' privacy concerns [MZF20, SMFM22], future safety and security features should also focus on providing users with the means to establish safe spaces where they feel comfortable disclosing information to others.

As Study 2 revealed, socializing and conversing with others is integral to consumer social VR. Thus,

conversation-related social processes, like self-disclosure, inherently shape the social experience in social VR and how users eventually establish meaningful connections by, e.g., disclosing increasingly personal information. Thereby, as VR complements verbal communication with natural non-verbal communication cues not available in other mediated communication venues, i.e., social touch, it empowers users to express the intimacy created via self-disclosure in more manifold and natural ways, resolving limitations identified with other platforms for online self-disclosure [TGL+22]. Ultimately this increased expressiveness holds implications for how VR may benefit the formation of close relationships over distance in the future [HB19]. And given the importance of self-disclosure for healthy relationships and, eventually, mental well-being [AT73, Sto87, KD02, TGL+22], it is crucial to design social VR in such a way that users find the very conditions, e.g., social contexts discussed in Study 3, and manifold interaction types like social touch, that they need for self-determined self-disclosure.

Almost There

Study 4 also relates to all areas of interest from Study 2. Foremost, although simulating co-located gaming in VR is a particular use case, it is an illustrative example of a gaming activity and, thus, how social VR can address entertainment needs in ways that people are familiar with, given that co-located gaming is a popular social leisure activity. Other examples of entertainment use cases utilizing VR from related work include the simulation of photo-sharing experiences [LKR+19] and joint video-watching [MLC+22].

Concerning the motives that drive social VR engagement, Study 4 exemplifies a famous real-world use case where VR can provide a convenient way to meet and enjoy a specific activity without requiring people to take a car or public transport. Further, extending previous studies [LKR+19, MLC+22], based on the experiential similarities between the VR and f2f condition, it showcases how social VR can be a substitute for real-world social interaction.

Specifically, how we set up the spatial layout in the study with the shared physical and virtual sofa illustrates how VR introduces spatiality to remote social interactions that other venues can not. Considering that online gaming via PCs or consoles usually connects players only via voice chat, this spatial component, exclusive to VR, presumably contributes to users' perception of social VR being superior due to the increased sensory immersion and perceived illusions of place and social presence [SGZM21, SKE+23].

While the results of Study 4 and related work indicate that social VR experiences are almost at the level of their f2f counterparts in selected use cases, they also provide a context to discuss wanted improvements that users indicated in Study 2, i.e., extended tracking capabilities and increased sensory immersion. For example, many participants in Study 4 said they would like the avatar to represent legs, which would further increase behavioral realism and the ability to identify each other's affective state based on the pose the players take on the virtual sofa [SKE+23]. Extending the tracking capabilities and virtual user representations have been demonstrated to be beneficial for the social experience by other authors [HOB18, AI21, WWJ+21]. Our and related studies' most significant tracking-related limitation was the lack of face-tracking [LKR+19, MLC+22, BRP+23]. In particular, combined with the still limited field of view offered by the VR headsets, those limitations mainly caused the experiential differences between the VR and f2f scenarios [LS21, MLC+22, SKE+23].

Notably, the participants of Study 4 were not active consumer social VR users at the time of the study. Still, they highlighted the same benefits of VR compared to other technologies as the active consumer social VR users in Study 1. Consequently, most participants showed openness to using the tested scenario privately, indicating that social VR will be more broadly accepted and used for remote social interaction once the technology becomes less expensive and more polished. Thereby, Study 4 illustrates that social VR does not necessarily need to offer genuinely novel activities and social experiences but can have social value beyond existing technologies by replicating activities that people are already familiar with and value so that they can experience them at a distance.

4.2. The Most Social Platform?

To infer an informed evaluation of the guiding question of this dissertation the following two criteria are used to translate the findings of Study 1-4 into an assessment of the current state of the sociality of VR: (i) indications that social VR is actually used as a social platform and (ii) social VR's resemblance to the gold standard of f2f interaction.

A Social Platform
Concerning criterion (i), Study 2 shows that current consumer social VR applications are social platforms. Various social motives drive user engagement, and social activities are essential to the user experience. Study 3 further shows that self-disclosure in consumer social VR serves social goals and is affected by social context factors. Not directly linked to actual consumer social VR applications, Studies 1 and 4 also show that VR can be a social platform by illustrating its potential to offer specific social interactions or social activity contexts. Study 1 induced a sense of social presence in participants and demonstrated the influence of social factors, such as intimacy conveyed through various types of social body contact, on the emotional response to virtual touch. Finally, in Study 4, participants experienced a rich social experience in VR that also increased connectedness after the interaction. Thus, concerning the guiding question, this dissertation indicates that current consumer VR technology can be considered a social platform.

This conclusion aligns with the findings from the social VR research areas presented in section 2.3. In particular, the social VR design literature shows that the platforms are at least conceptualized as social places where specific features facilitate user interaction. Our and others' findings (e.g., [ZF19, MF20, MZF20, FA21]) validate the intentions of platform designers interviewed previously [MSKI19] by showcasing that social VR applications address specific social needs and support rich social experiences for diverse groups of users with distinctive motivations.

A Social Platform Resembling Face-to-Face Interaction
Due to its immersive characteristics, social interaction in VR can technically mimic f2f interaction in how certain types of interactions are performed and audio-visually perceived. Study 1 illustrated this with the investigation of virtual social touch, and Study 4 with replicating a social scenario with a specific spatial constellation of users. Consequently, concerning criterion (ii), this dissertation showcases that VR technology can mimic f2f interaction scenarios and thus be considered a particular social platform if f2f serves as a "gold" standard. Further, the results of all four studies provide evidence that, as a consequence, user behavior and experiences also mimic f2f interaction. Study 1 indicates, in line with related work [FLTA21], that virtual social touch response is affected by a set of influence factors that also affect responses to physical social touch. Study 2 illustrates, based on day-to-day user experiences, that some users use consumer social VR as a substitute for real-world social connections and that the main benefits of social VR lie in the increased expressiveness and naturalness due to the immersive characteristics. Study 3 illustrates that social context factors that affect f2f self-disclosure also affect social VR self-disclosure decisions. Finally, Study 4 directly compares a f2f and VR scenario and found both inducing very similar experiences that, in a real-world use case, probably would not make a significant experiential difference.

Since sensory immersion combined with motion tracking is the defining feature of VR, it is not surprising that the naturalness of social interaction and social experience is the subject or outcome of various social VR research efforts. Thus, our findings align well with related work, and social VR literature indicates that consumer social VR is a f2f-like social platform. This is mainly due to nonverbal affordances that mimic f2f communication [MFW20]. However, current technical limitations partly require designers to invent specific control paradigms to control something like a virtual mimic, as long as face-tracking is not integrated into VR headsets [THB20]. Day-to-day experiences also highlight a resemblance of f2f interaction and experiences, e.g., in long-distance relationships [ZF19] or family meetups [ZF23]. Further work with novice users also indicates the f2f resemblance in the context of small group interactions [MS18], photo sharing experiences [LKR+19], proxemic behavior [WLV+21], and joint video watching in

VR [MLC+22]. Furthermore, several prototype studies unveil behavioral similarities between social VR and f2f interaction, e.g., regarding conversational patterns [SN18], nonverbal synchrony [SSW19], personal space zones [BPB20], behavior during meetings [AKLN21], and compliance behavior [DKGS22].

A Social Platform with Distinctive Features

Studies 1, 2, and 4 indicate that VR is a platform with distinctive features that potentially enable it to be more social than alternatives. Concerning criterion (i), Study 2 directly unveils the benefits users attribute to consumer social VR compared to other digital places like online games and social media. The two most frequently mentioned advantages are the immersive experience and overall better quality of social interaction in social VR, i.e., users behave more authentically and naturally, and interactions are more meaningful and memorable. Further, many users indicated they experience a social closeness in VR that they can not find elsewhere. In relation to criterion (ii), Study 1 serves as an illustrative example of how VR can replicate a fundamental and intimate form of social interaction, i.e., social touch, due to its immersive characteristics in a way that resembles how it is performed and perceived in f2f communication. With other non-immersive technologies, this degree of replication is not possible. Based on this purely technical capability, VR supports distinct forms of social interaction that may eventually generate exclusive social experiences. Further, Study 4 is an example of how VR enables the simulation of entire f2f activity contexts in which the spatial relationship between users and the shared environment is an essential part of the atmosphere. In the use case of Study 4, this is sitting together on a couch, which, again, other technologies can not replicate the same way.

Again, this conclusion aligns with the broader social VR literature landscape, that illustrates how current social VR applications offer distinctive features and experiences compared to other technologies. Literature on day-to-day experiences exemplifies how VR's technical exclusive features benefit facets of social interaction by demonstrating how avatar embodiment contributes relationship-building [FA21], allows the engagement in embodied activities like dancing [PHM22], and experiencing virtual social touch [AY22]. Other examples of exclusive qualities of social VR reported in the literature are sleeping together in sleep worlds [MF20], innovative social support features for marginalized user groups [LFSA23], and the possibility of replicating f2f gatherings in close relationships like birthday parties [ZF23]. And also, lab-based prototypes, e.g., in the context of virtual social touch, illustrate the exclusive social interaction opportunities of VR [CKM21, FLTA21, SM21, DSSL+23]. Unfortunately, there also seem to be distinctive qualities with negative connotations, as the embodied experiences enable novel forms of harassment that challenge users and developers alike [BEEDS19, FZMA22, SLF+23]. However, recent proposals highlight the potential of VR to have distinctive experiential qualities not only compared to other social platforms, but also f2f interaction [MSI21].

A Still Emerging Social Platform

Apart from the positive evaluations above, all four studies indicate that VR is still an emerging social platform. Although Study 1 shows how social VR can mimic f2f interactions in principle, it also demonstrates that virtual social touch is not on a par with its physical equivalent in sensory terms. For example, the technology still needs to be advanced enough to replicate realistic haptic experiences at the consumer level. Even though haptic technologies are under ongoing research, it will take some time before market-ready, inexpensive, and easy-to-use home-use devices exist. At the same time, the software requirements to realistically recreate virtual social touch is also a non-trivial factor. In Study 1, for example, we used an approximation to trigger and render the virtual body collisions along predefined, fixed anchor points on the avatars. This was mainly due to the lack of hand tracking. Eventually, when hand tracking started to be integrated into VR headsets, we developed approaches that allow us to generate physically correct collisions between avatar models, in particular the hand and finger models, in real-time and synchronized between online users (see [DSSL+23] for a recent related work example). However, such avatar-avatar collisions are not a standard in consumer applications, where avatars usually still permeate each other or become transparent if they get too close. However, against the background of the emergent harassment

issue [BEEDS19, FZMA22], this is probably still a preferable approach. Study 2 directly indicates areas where users want social VR to be improved. On the one hand, they refer to features that would make social VR even more realistic, such as better and more extensive tracking and the inclusion of additional sensory modalities. On the other hand, however, social VR applications can still improve their social features through even more diverse social activities, better contact management, better security features, and more flexible integration of social VR into other communication channels. In addition, Study 3 unveils, in line with related work [MZF20], privacy concerns, an area that recently became more focused by researchers [NGS22a, LL22]. Study 4 illustrates that, in specific use cases, social VR experiences can closely approximate their f2f counterpart. However, like other studies, [LKR+19, MLC+22, BRP+23] it also highlights one significant technical advancement, which would further benefit the realism and overall sociality of social VR: the addition of face-tracking. Face-tracking has recently become more accessible with the launch of the *Meta Quest Pro*, and future work has to show what features users will ask for once they get accustomed to the extended tracking. Surprisingly, many participants also missed avatar legs, validating *Meta's* recent efforts to provide realistic leg animations without requiring users to wear additional tracking hardware.

Apart from specific technical limitations that will probably be solved in the coming years, the social VR design literature also exemplifies how the genre of social VR is still emerging, as platform developers have different approaches to the design of sociality [MSKI19], the design of avatar systems [KMSI19, HPDW22], and the implementation of nonverbal communication affordances [THB20]. Further, general usability issues must be resolved to ensure that future users have positive first-contact experiences [LS21]. Similarly, researchers and developers alike are advised to find solutions to emerging forms of virtual harassment [BEEDS19, FZMA22, SLF+23], privacy concerns [MZF20, SMFM22, NGS22a, LL22], and to ensure social VR being an inclusive and supportive venue for diverse user groups [AF21, ZDL+22, LFSA23].

In summary, the results of this dissertation and its related works illustrate current consumer VR technology offering access to meaningful social experiences that afford interaction dynamics and experiences that resemble f2f interaction. The interaction paradigms exclusive to VR technology provide experiential benefits for current users compared to other non-immersive technologies for social interaction at a distance. However, apparent technical limitations and the vast design space for novel features beyond replicating reality invite researchers and developers alike to further shape this young but promising technology for remote social interaction.

4.3. Limitations

Besides the study-specific limitations discussed in the individual publications 1-4, this dissertation itself is also subject to limitations. Those lie in particular in the overall framing under which the four studies are used to answer a broad guiding question. While a common theme fundamentally connects the four studies, this dissertation does not use a theory-driven connection. Each study considers an isolated topic area in the context of consumer social VR applications without building on common ground, for example, by eliciting the same set of variables or using the same methods. On the contrary, the individual studies address different research questions using different methods and focusing on relevant variables in the respective contexts. Therefore, the contribution of this dissertation does not lie in the further or new development of a specific theory, for example, the experience of social presence in immersive social VR, but, as explained in the introduction, in the momentary examination of consumer social VR applications from different perspectives that eventually provide a set of thematic starting points for future theory-building on social experiences in consumer social VR. Offering a series of such starting points is essential given that consumer social VR is still an emerging genre and subject to numerous technical and design challenges that researchers and developers must solve in the coming years if they want social VR to be a safe and widely used space for interpersonal communication.

The absence of a grounding theory is related to another limitation of this dissertation. A provocative, non-scientific assumption about VR (and AR) serves as the basis for the guiding question of this dissertation which is discussed considering two loose criteria that were neither used uniformly across the four studies nor considered to define a set of recurring specific variables to investigate across all four studies. Thus, the four studies do not allow an elaborate conclusion about how VR may be social to any particular degree based on a specific set of dependent variables that represent an isolated perspective on the matter. On the contrary, the contribution results from simultaneously considering several isolated perspectives, considering lab-based and everyday user experiences, and converging the different perspectives and experiential facets under a provocative overarching question. Due to the young age of the applications, the still low penetration of the technology in general, and the observable difficulties of enterprises such as *Meta*, it is not at all conclusively defined what social VR applications can be, what they can look like, what features they can offer, and what use cases they open up. Further, the current literature and platform landscape illustrate that social VR can look and be used in very different ways in various use cases by very diverse user groups. Accordingly, a purely isolated consideration of a coherent set of selected variables alone is not practical at the current time. Instead, diversified perspectives, such as this dissertation, can initially help to unveil starting points and relevant variables for more isolated follow-up research.

A third limitation is that none of the studies included in the body of work compared social VR to other platforms of interpersonal communication. In contrast to providing platform comparisons that may not be meaningful, this dissertation focused on unveiling fundamental experiential qualities and day-to-day uses of social VR that had to be addressed in this still-emerging literature domain. Of course, this dissertation subsequently does not allow any conclusive statement that refers to the experienced sociality of VR compared to other technologies. Though, as described in the background chapter on social presence, it is not necessarily expedient to compare VR directly with other technologies regarding the social experience since users can also become accustomed to the affordances of communication mediums and have comparable social experiences quite independently of any technical limitations. What this dissertation nevertheless enables, however, is the formulation of assumptions about the social experience in VR based on its distinctive quality to replicate certain f2f social interactions that other technologies like video calls can not copy (i.e., social touch and sitting together on a couch). And the platform comparisons made by the participants in Studies 2 and 4 allow at least a limited comparison based on user opinions. Further, a direct comparison is not necessarily reasonable as there are fundamental differences between VR and other platforms, like social media, regarding the primary mode of communication. Whereas established social media platforms focus on sharing information asynchronously with many users, current social VR is designed for real-time interaction among smaller groups of interactants. And since social VR is still a young medium, it remains open in which use cases a direct comparison of VR and other technologies could be meaningful in the first place. Eventually, this dissertation aids identifying such use cases.

A final limitation of this dissertation in terms of answering its guiding question is the temporal validity of the findings. This limitation, of course, affects nearly all research involving continuously evolving technologies. Nevertheless, it is crucial to consider the significance of this continued development to evaluate the research. Consequently, this dissertation cannot answer whether VR will be the most social platform in the future. The degree of VR's sociality compared to other technologies depends on further advances in VR technology and other technologies. For example, recent advances within the VR technology frontiers have direct relevance for the validity of this dissertation. Shortly after finishing Study 4, *Meta* released the *Meta Quest Pro* that integrates face-tracking and likely directly resolves a significant weakness we identified in the VR scenario in Study 4. While face-tracking is not yet a default feature and the *Meta Quest Pro* is designed less for entertainment purposes than for business use cases, it shows that crucial technical development steps are already starting and are about to become more widespread. This limitation is discussed explicitly in publication 4, but in the context of the other publications, this dissertation's time horizon is also an important factor. Just as this dissertation is a snapshot of the state-of-the-art technology accessible to consumers between 2018 and 2022, it is also a snapshot of the users that used consumer social VR applications comparatively early on (Studies 2 and 3). Whether future user groups

will exhibit the same usage motives and behaviors as those early users remains to be seen. In the same way, most participants in Studies 1 and 4 had no prior social VR or VR experiences, probably because the technology and application type are currently not widespread and known in society. If the technology becomes more widespread and famous in the coming years, people are more likely to have prior experiences with or at least an informed opinion about it. Consequently, novice users in lab studies may become rare or already have specific reasons for not engaging in social VR in their private lives. However, even if this dissertation does not provide a long-term assessment, it makes a lasting contribution to the field by providing a base value of the sociality of current social VR that can be referred to in the future to evaluate the effects of technological advances and new user groups on sociality in social VR.

4.4. What is Next?

Apart from specific follow-up research opportunities discussed in publications 1-4 and research opportunities implied by the above limitations, there are broader implications for future directions of consumer social VR research. First, the four areas of research described in section 2.3 offer distinctive perspectives for identifying numerous specific starting points for follow-up research. Given the continuing advances in VR technology and platform design due to the involvement of big tech companies, all of those four areas will likely continue to be relevant in the coming years. For a future assessment of the guiding question of this dissertation, future work should consider the four broader perspectives illustrated in Figure **4-2**): the day-to-day use of social VR applications, risk factors, distinctive features of VR, and psychological outcomes of social VR engagement. In particular, the continued assessment of everyday user experiences will provide insights into how users will use and integrate social VR into their daily life as alternatives or additions to existing communication technologies. Simultaneously, there is ongoing need to unveil the effects of engaging in social VR, such as on users' psychological well-being or their satisfaction with their social lives, as initial studies have already begun to do [BAH22, vBAH23]. Combined with a continuation of systematizing social VR design approaches, this also should enable developers to build social VR applications to evoke the intended sociality purposefully. Efforts should also be made to obtain data on which user groups will eventually start and continue to engage in social VR and unveil the reasons for and against its use.

The further dissemination of social VR depends on the acceptance of VR technology in general, which in turn depends on the attractiveness of the devices (e.g., ergonomics, ease of use, additional required hardware, performance), the market prices, and the perception of consumers that VR serves specific use cases that might be interesting for them. Further, recent work identified potential psychometric predictors for VR adoption (e.g., immersive tendencies) [CCWZ22]. However, more general perceptions of *Metaverse* technologies like VR and social VR also seem to influence users' willingness to engage in applications like social VR and can be considered risk factors for VR adoption. A recent study indicates what types of people may be more likely to migrate to a future *Metaverse* in their daily lives [OWP23]. By asking gamers of open-world games and a sample representing the polish society, the study found that the individual willingness to migrate to a future *Metaverse* is higher if one is already attached to virtual places, like games. However, among the sample, there was a general tendency against migrating to a future *Metaverse* that relates to perceived threats like privacy concerns and losing access to human experiences. Although indicating relevant factors that may determine future user engagement, the nature of the data only allows an early assumption. Eventually, future user studies must assess factors determining user adoption of applications like social VR based on first-hand experiences. Although not in private contexts, recent literature provides examples of longitudinal investigations of social VR engagement in productive contexts [BRP+23, HMD+23] that provide a blueprint for conducting such studies in leisure activity contexts to unveil private adoption processes.

Resonating with the identified influence of perceived threats of the *Metaverse* on peoples' willingness to engage in it, data security and privacy are recently becoming recognized as significant directions in

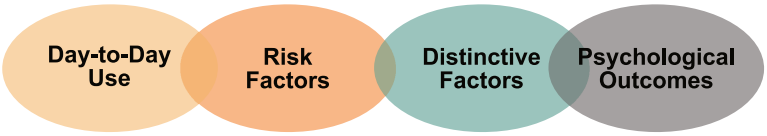

Figure **4-2**.: Four broad perspective for future social VR work.

multiuser and consumer social VR research. For example, a recent overview paper identifies substantial research and development gaps in the area of digital identity in social VR related to the generation, use, authentication, and protection of avatars [LL22]. Illustrative examples for research and development in this context are two recent complementing preprint papers that showcase how VR user data can be used to infer personal data attributes like body attributes and demographic information [NGS22a] and propose a software plugin that helps to secure such data [NGS22b]. As concluded in the overview paper, the broader acceptance of social VR technologies will heavily depend on the success of such privacy and security efforts, whereby research already seems to lack behind the practical demand [LL22]. Further, public controversies surrounding the companies that offer *Metaverse* technology, like *Meta*, probably also determine whether and how successful VR, and eventually social VR, will be.

In addition to mitigating the above risk factors, research should also be particularly concerned with transforming the distinctive technical affordances of VR into meaningful social experiences [MSI21]. Again, the possibility of social touch serves as an illustrative example. On the one hand, VR can replicate the act of touching others and thus potentially offer qualitatively different social experiences than other communication media. Considering the effects of purely visual touch [SM20, FLTA21, AY22, DSSL+23] and the anticipated and desired progress in the development of haptic feedback devices [CKM21, vHHTvE22] social touch may be a significant contributor to social experiences in VR in the future. Complementary, systematic efforts assess what kind of touch interactions people would like to see enabled in technology-mediated communication [RBG+22] and how touch-based messages can be translated into specific haptic patterns for haptic feedback devices to be universally intelligible in mediated interaction [RSFHO+22]. On the other hand, as also described in the literature [RBK+19, MSI21, SM21, ISK+22, DSSL+23], virtual social interaction like interpersonal touch can consciously deviate from reality if developers take advantage of the creative freedom of the medium. In particular, the combination of the familiarity of interaction, i.e., how virtual touches are performed (just as in f2f), and the potential distinctiveness of the multisensory presentation of virtual touches may be the key to transformative social experiences that other media and even the real world cannot replicate. Correspondingly, to do justice to touch's role in human development and well-being, researchers and developers already call for defining an agenda for mitigating risks and opportunities when transferring social touch into the virtual realm [JPS+21].

5. Conclusion

The Covid 19 pandemic has highlighted the importance of enabling social connections at a distance. At the same time, technology companies continually strive to develop how people can have shared experiences across spatial and temporal barriers. In particular, *Meta*, formerly *Facebook*, a company that has already had a socially far-reaching impact on technology-mediated communication, publicly proclaims that with technologies like VR and AR, the ultimate social platform is making its way into people's everyday lives. And yes, since the introduction of modern consumer-level VR devices within the last decade, the modern network infrastructure and computational power have enabled immersive social experiences to a scale and quality impossible in previous generations of VR technology. But how social is this platform? VR is far from being a widespread technology among private users and, in this context, promises to be a new platform for digital games in particular. Therefore, the extent of VR's value as a social platform has yet to be assessed. However, the current first generation of consumer social VR applications allowed an initial approach to answering the question: **Is VR the most social platform ever?**

This dissertation offers four exciting perspectives on this question and provides insights into fundamental aspects of sociality that current consumer social VR technology offers. By investigating virtual social touch, it unveiled emotional reactions and moderating factors of the virtual version of one of the most intimate forms of social interaction. Directly asking current users, it unveiled the motivations that drive day-to-day use of consumer social VR platforms. It further unveiled how social VR users engage in self-disclosure, one of the fundamental processes of socializing and relationship-building. Finally, it illustrated how current consumer VR technology, despite technical limitations, can generate rich social experiences in a popular leisure context nearly equal to the f2f alternative. The individual perspectives taken in this dissertation contribute practical starting points for the further design and research of social VR experiences. The insights into virtual social touch have implications for designing embodied social features, such as the appropriateness of specific types of touch in different contexts and the need to give users control over the experience of this intimate form of expression. The results of the two international online surveys identify a whole range of specific starting points for developers and researchers. For example, developers can check whether their platforms are used for social reasons and which features need improvement to enhance the overall experience further. Researchers can identify use cases relevant to users' everyday lives from the results, which they can investigate more profoundly concerning specific theories of social interaction in social VR. Eventually, the direct comparison of a f2f and virtual version of a popular social leisure activity informs follow-up research for extended theory-building regarding the interplay between social VR features and experiential qualities by providing a baseline measure for the future comparative evaluation of experiential outcomes introduced by technological advancements in the coming years.

In conclusion, this dissertation contributes an exploration of the experiential qualities and day-to-day value of social VR applications available for consumers based on lab studies and the thoughts and behaviors of current social VR users. These studies indicate, that current consumer VR offers access to meaningful social experiences very similar to f2f interactions, despite current technical limitations. Due to its immersive properties, it is fundamentally technically different from other social platforms. Yet, only future work can conclusively assess to what extent this makes VR more social than alternatives. However, VR offers an only rudimentarily explored design space for remote social interaction that promises to provide social experiences beyond alternative offerings and reality in the future. Developers, researchers, and users alike are invited to leverage the potential demonstrated in this dissertation.

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A. Attached Publications

A.1. The Experience of Social Touch in Multi-User Virtual Reality

Philipp Sykownik and Maic Masuch. 2020. The Experience of Social Touch in Multi-User Virtual Reality. In Proceedings of the 26th ACM Symposium on Virtual Reality Software and Technology (VRST '20). Association for Computing Machinery, New York, NY, USA, Article 30, 1–11. https://doi.org/10.1145/3385956.3418944

The Experience of Social Touch in Multi-User Virtual Reality

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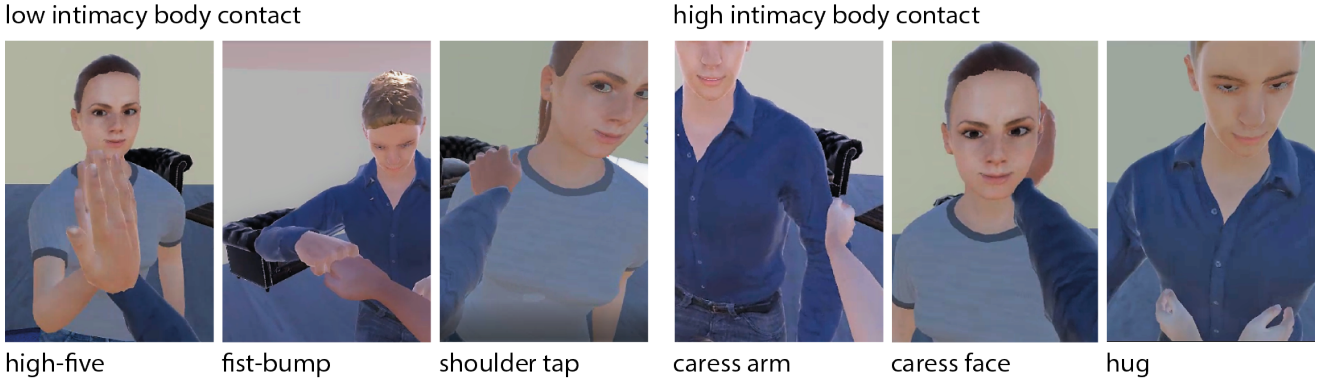

Figure 1: Participants performed the interactions depicted above with a physically remote research assistant in VR. We compared the emotional experience of the two intimacy groups (high vs. low intimacy) regarding the influence of intimacy, direction of touch and sex of participant.

ABSTRACT

We present user study results on virtual body contact experience in a two-user VR scenario, in which participants performed different touches with a research assistant. The interaction evoked different emotional reactions in perceived relaxation, happiness, desire, anxiety, disgust, and fear. Congruent to physical social touch, the evaluation of virtual body contact was modulated by intimacy, touch direction, and sex. Further, individual comfort with interpersonal touch was positively associated with perceived relaxation and happiness. We discuss the results regarding implications for follow-up studies and infer implications for the use of social touch in social VR applications.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **Virtual reality**; *Laboratory experiments.*

KEYWORDS

social VR, multi-user VR, virtual reality, social touch, mediated social touch

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1 INTRODUCTION

Given the advance of current VR hardware and ambitions in developing social VR environments such as *Facebook Horizon*, embodied social interactions within virtual worlds are now more accessible than ever. For instance, virtual social touch is already used as a social feature that adds to the overall user experience (e.g., a handshake for friending in *RecRoom*). Unfortunately, the freedom of embodied social interaction like virtual social touch seems not to be limited to positive experiences, as physical harassment (e.g., unwanted "touching" of avatars) is already occurring in social VR applications [5]. However, based on a current taxonomy for the design of social VR research and industry applications, social touch does not yet seem to have received significant attention in studies on social VR [29]. Although the taxonomy identifies physical expressions from the body of literature as a communication type of interest in current VR prototypes, the work cited in the taxonomy does not yet investigate this communication type as an independent feature. Further, a recent overview of nonverbal communication channels utilized by current social VR platforms also indicates that social touch is not yet considered as a core feature [56]. However, as interpersonal touch is so vital for human interaction in the physical world [12, 30, 47, 52], we do not see any reason to believe that it should not become a central aspect of virtual social interaction in the future. Therefore, we investigate the emotional reactions to virtual body contact to aid the design of virtual social interactions.

2 SOCIAL TOUCH

Humans have a natural need for social physical contact, and touching and being touched are evolutionary established basic modes for interaction [8, 12]. Early observational and more recent self-report studies indicate that the use and subjective evaluation of interpersonal touch in the real world underlies complex interactions of influencing factors like the social context, sex, direction of touch, the type and location of touch, and the type of relationship between interactors [15, 19, 24, 46, 53, 54].

Interpersonal touch is one of the primary means to foster and express intimacy between each other [24, 57], and different types and locations of touch are associated with varying degrees of intimacy [24, 30]. Generally, areas, where touch is perceived as less intimate are the hands, arms, and shoulders. These areas are allowed to be touched by strangers or emotionally distant acquaintances. Moderate intimacy areas include the face, stomach, chest, buttock, and the back of thighs, which are at most accepted to be touched by close friends, family members, or the partner. High intimacy areas are the thighs' insides and pubic areas and only accepted to be touched by the romantic partner. This classification is more or less consistently reported in the literature. However, it can differ in varying degree depending on the direction of touch (initiator and receiver), sex of touch initiator and receiver, their cultural background, and emotional bonding [25, 54, 58], as well as their sexual orientation [14], and individual traits like social anxiety [31, 51].

Among the various influencing factors, sex is one of the most often studied moderators on the effects of touch [24], and a recent meta-review of work concerned with the neurophysiology of affective touch supports the early indications regarding a moderating effect of sex on social touch perception [46]. Whereas for heterosexual women, in particular, a touch must reflect the relationship's intimacy to be appropriate and pleasant, heterosexual men tend to perceive intimate touches from stranger women as pleasant [25]. Generally, heterosexual women and men tend to prefer touches from women over touches from men [53, 54, 58]. Compared to different-sex touches, same-sex touch among heterosexual strangers was found to be often rated as unpleasant or inappropriate, but women tend to be more open to it than men [13, 25, 54].

3 MEDIATED SOCIAL TOUCH IN VR

Modern VR technology can induce a strong illusion of virtual body ownership or a sense of embodiment [28, 34, 40, 43, 49, 50]. As a consequence of perceiving an illusion of virtual body ownership, a user may experience events affecting his virtual body, as if they would affect his physical body. Thus, observing one's virtual body being touched by or touching another avatar could induce similar reactions as being touched in the real world. Indeed, technologically mediated social touch seems to evoke physiological, emotional, and behavioral reactions similar to its real-world counterpart [18, 27, 60, 60]. These findings mainly stem from the evaluation of haptic feedback devices that often transmit haptic stimuli independent from the visual presentation of the interaction [1, 18]. However, the development of such interfaces, in particular, to enable realistic haptic interaction in consumer VR, is an ongoing research area, that does not seem to evolve into affordable consumer-level devices soon [3, 9, 38]. Though, research on cross-modal sensory interactions indicates that visual cues alone seem to sufficiently induce reactions similar to being touched [4, 6, 41]. And as modern consumer VR technology is already a remarkable visual medium, we highlight the importance to understand the reactions to mediated social body contact that is primarily induced by visual cues generated by such hardware.

Findings from studies that used VR technology are based on diverse hardware and software configurations, sometimes limited by the technology available at that time. However, they can be classified according to the interaction partners (human-human vs. human-agent) and the direction of the touch investigated (participant initiates vs. receives touch).

One of the most recent studies compared human-agent and human-human interaction in VR were participants received a touch on their physical shoulder. The results indicate that incorporating social touch in the virtual interaction could increase the touching virtual agent's perceived humanness but not of the human-controlled avatar's[26]. Another recent study (human-agent, receiving touch) found that the perceived appropriateness and erogeneity of virtual touch on different body zones of an embodied avatar seem to be modulated by the same influencing factors as physical touch (i.e., the location of touch on the virtual body, the sex of the touching avatar and the touched participant, and sexual orientation). The touches were induced solely by visual stimuli [14]. Another relatively recent study (human-agent, receiving and initiating) that offered low immersive fidelity compared to the two prior studies investigated the role of touch in economic decision making [55]. Contradicting to previous findings in VR settings (human-agent, receiving touch) [21, 65], the authors found no effect of touch on compliance behavior [55],

In a study on how anti-fat attitudes affect touching behavior with force-feedback devices in VR (human-agent, initiating) touch duration and strength were affected by factors like sex, anti-fat attitudes, and the virtual agent's characteristics, similar to face-to-face studies from that field [59]. Another study from that time (human-agent, receiving) found that virtual touch perception supported by tactile feedback seems to be modulated by facial expressions of the touching and individual differences related to participants' sex [20].

Seemingly the only prior study that investigated the effects of virtual touch in a multi-user VR scenario investigated the role of physical feedback to a received touch on one's virtual shoulder on the tendency to engage in an embarrassing social situation (i.e., sing in front other avatars) [7]. Tactile feedback to the touch did not indicate increased the tendency to sing, but the perceived realism of the touch [7]. An early study (human-agent, initiating touch) found that virtual agents tend to be touched with less force than virtual geometric objects using a force-feedback input device. Further, the force used on virtual agents depended on the location of the touch and the sex of the agent [2].

This short review illustrates that previous studies have rarely investigated direct emotional responses to virtual touch. If, only in limited ways and not in terms of several distinct emotions [14, 26]. Most studies have been interested in the haptic experience of touch

Table 1: Application Structure

Scene	Purpose
Tutorial	Avatar customization: leg and arm length, sex, hair, skin tone, eyes. Virtual mirror. Dummy model to practice touches.
1st Interaction	Each user initiates and receives several social body contacts of intimacy group 1.
Pause	Users wait in separated virtual rooms in front of a mirror before entering the second interaction scene.
2nd Interaction	Each user initiates and receives several social body contacts of intimacy group 2.

[7, 20], touching behavior, and behavioral responses [2, 7, 55, 59, 65]. Further, in particular, older but also some recent studies used hardware and software configurations that only provided limited immersive characteristics compared to today's available hardware (e.g., no virtual user representation [26, 55], no full-body movement [14]). Thus, we consider investigating the affective reactions to virtual touch in terms of distinct emotions in a multi-user VR scenario that resembles the immersive quality of current consumer social VR applications as a valuable contribution to this research field.

4 APPLICATION DESCRIPTION

We developed a two-user VR application that requires users to perform various social body contacts while providing full-body user representations and movement tracking (see Figure 1). Table 1 provides a quick overview of the application structure.

Both users go through a tutorial scene separated from each other to take enough time to prepare for the actual interaction. The tutorial scene has three functions. The first is to familiarize users with the virtual environment and hardware. Further, their avatars' individualization in front of a virtual mirror should promote presence and embodiment [61]. Finally, users can become familiar with the execution of virtual body contact by practicing the social touch interactions on a static dummy avatar model.

We designed the two interaction scenes as a series of simple interaction tasks, where users have to perform different social touch interactions from one of the two groups that Figure 1 illustrates. The interaction takes place in a virtual living room where a monitor displays the interactions to perform. The application recognizes correctly performed interactions, plays a confirmation sound, and updates the virtual monitor's instructions correspondingly. For interactions with an initiator and receiver role, the system indicates who should initiate the interaction (e.g., A hugs B). In sum, the application requires each user to perform the following interactions:

- **low intimacy body contacts**: 8x high-five, 8x fist-bump, 4x initiating shoulder tap, 4x receiving shoulder tap
- **high intimacy body contacts**: 5x initiating caress arm, 5x receiving caress arm, 5x initiating caress face, 5x receiving caress face, 5x initiating a hug, 5x receiving a hug

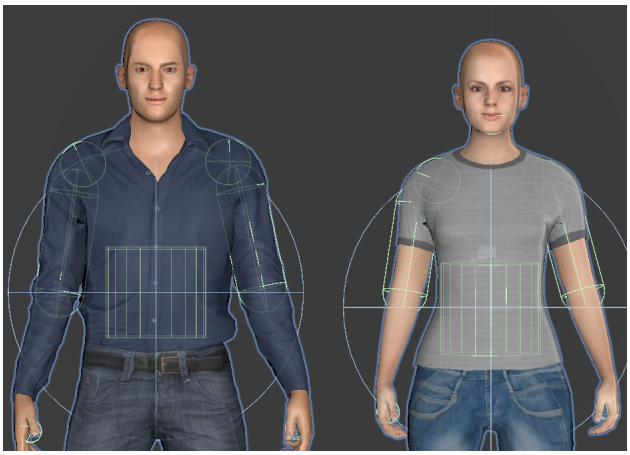
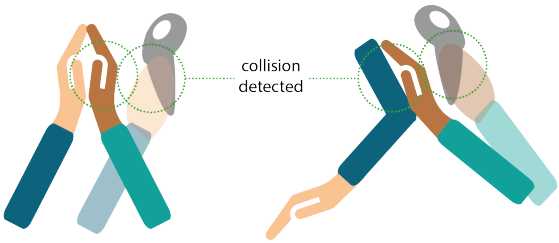


Figure 2: Avatar base models with colliders that trigger pseudo-haptic effects on collision with virtual hands: partner's hands, head, shoulders, upper arms, and abdomen.



a) virtual hand does not permeate certain other body parts

b) collision of the virtual hand with near body parts is maintained

Figure 3: Our pseudo-haptics approach: a user's virtual hand is decoupled from a trigger object that follows the user's physical hand's movement. This decoupling is triggered when the collider attached to the trigger object collides with colliders of certain target body areas.

A pause scene separates the two interaction scenes. There, users can get used to the VR setting again after filling out desktop-based questionnaires in a study setting.

4.1 Selection of Social Touches

Figure 1 presents the six social touch-types we used to induce low and high intimacy during the interactions. High-five, fist-bump, and shoulder patting are interactions related to body regions and tactile stimuli associated with low intimacy [25, 58]. Caressing the arm and face, or touching the torso (hugging) are associated with high intimacy [25, 58].

4.2 Avatar Collision

To prevent users from permeating each other's avatar and thus increasing realism, we used pseudo-haptic effects. Pseudo-haptics aim to simulate haptic perceptions using visual cues [36, 37], usually realized by creating a positional offset between the virtual and

physical hand and have recently found to positively affect the immersive experience and enjoyment during interaction with virtual objects [44].

In our application, we added colliders to specific body areas of the avatar models (Figure 2). Thereby, the colliders associated with the avatar hands serve a particular function, as these are not attached to the virtual hands but an empty object that, in turn, follows the respective physical hands' movements. During the interaction, each avatar hand follows this object. When it detects a collision with a specific body part (e.g., the other user's upper arm), the associated hand model is attached to that location with a predefined pose. At the same time, the empty object keeps following the user's physical hand. The virtual hand, however, remains attached, as long as the hand collider detects a collision with the target area (Figure 3). Further, touching the other avatar triggers vibrotactile feedback from the Vive controller.

4.3 Apparatus

The application was developed with the Unity game engine and tested with wireless HTC Vive and Vive Pro headsets. The avatars were created using the MakeHuman software and animated based on tracking information and inverse kinematics using the Final IK library for Unity. For simulating eye gaze behavior, we used the Simple Eye Gaze plugin for Unity. The networking components of the application were implemented using the Mirror Networking API. Voice Chat is not supported. User movement is tracked with the VR headset, two Vive controllers, and two Vive trackers mounted to the feet. Virtual hand postures can be adapted by pressing the grip button for a flat hand or trigger button for making a fist.

5 USER STUDY

We contribute to the research on social VR and mediated social touch by evaluating the experience induced by virtual social touches of different levels of intimacy performed with a stranger. This scenario should reflect the social interactions in current social VR applications where users can interact with strangers worldwide. We evaluated the affective response in terms of several emotions of different valence. The stranger in our study was a remote research assistant to assert some degree of standardization. To control the potential influence of sexual orientation, we only recruited heterosexual participants that we required to interact with an avatar of the opposite sex. We let participants receive and initiate virtual social touches of different degrees of intimacy, to investigate the interrelationship between the direction of touch with intimacy and participants' sex. As we focus on the impact of intimacy, we subdivided only the intimacy groups into two separate interaction scenes, while integrating the receiving and initiating role in each of these two scenes. The alternative would have been to create four conditions. This design would have required participants to leave and enter VR three times between the conditions in contrast to only one time between the two conditions we have used.

5.1 Participant Information

We conducted a within-subject user study with 44 participants living in Germany (27 female) aged from 18 to 31 (M = 23, SD = 3.4). Participants customized their avatars to reflect their physical appearance (e.g., 24 participants selected the white, 16 the slightly tanned, three the tanned, and one the black skin color for their avatar). Most participants had few prior VR experiences: 2 use VR more than once a month; 13 indicated to use VR occasionally; 15 used VR once before; 14 never used VR before. Only two participants had prior experience with social VR applications. We recruited participants mainly at the university and via social network sites. Forty-one participants were students. Some students were required to collect hourly credits for passing a specific study course module and were compensated correspondingly (1.5 hours). The faculty's ethics committee approved the study.

5.2 Procedure

Participants were welcomed and informed about the course of the study. They were told that they had to interact in VR with another participant who was unknown to them and in another physical space. The male and female avatar variants of the researchers had the same visual appearance in each study run (see 1). After giving their consent, participants were asked to complete a desktop-based questionnaire on demographic data. They were then familiarized and equipped with the VR equipment. Audio instructions guided the participants through the application. Participants were asked to make their avatar resemble their physical appearance by using predefined assets (i.e., the color of skin, eyes, and hair, hairstyle). After the tutorial, participants completed the two interaction scenes in randomized order. VR exposure lasted from 20 to 35 minutes. Eventually, we debriefed participants and informed them that they interacted with a research assistant. After each interaction scene, participants completed desktop-based questionnaires assessing their experience.

5.3 Measures

5.3.1 Individual Factors. We measured the comfort with receiving and initiating interpersonal touch of the participants to evaluate if this real-world trait is associated with the experience of virtual social body contact. As a measure, we applied the Comfort with Interpersonal Touch (CIT) scale that requires to rate 6 items on 7-point likert-scale "strongly disagree" - "strongly agree"[62].

5.3.2 Immersive Experience. To control if the application offered a comparable immersive quality in both conditions (low and high intimacy), we assessed perceived spatial presence, aspects of virtual body ownership, and co-presence.

We applied the spatial presence subscale of the iGroup Presence Questionnaire (IPQ) [48]. Items were rated on a scale from 1-7 where higher scores indicate a higher presence. Four item scales ranged from "fully disagree" - "fully agree." One item scale ranged from "did not felt present" - "felt present."

To assess the possible sensation of embodiment based on movement tracking and avatar animation in our two conditions, we selected three items associated with body ownership and agency from an item pool used to construct an embodiment questionnaire [16] (items presented in Table 2). We selected only these three items as we considered them to be sufficient in terms of our analysis goal for the embodiment-related immersive experience. We thus did not intend to use them as a valid instrument to assess the extensive concept of embodiment but to analyze them on a per item basis.

Each item was rated on a scale ranging from 1-7 ("strongly disagree" - "strongly agree").

We applied the co-presence subscale of the Networked Minds Measure of Social Presence (NMMSP) [23]. This scale includes six items that allow us to rate how far our application generated a social situation with mutual attention and action-taking. Items were rated on a scale ranging from 1-7 ("strongly disagree" - "strongly agree").

We further applied the Simulator Sickness Questionnaoire (SSQ) to measure the perceived simulator sickness [33]. Spacial presence, embodiment, and co-presence were assessed after each interaction scene. The SSQ was applied at the end of the experiment.

5.3.3 Emotional Experience. We applied the Discrete Emotions Questionnaire (DEQ) [22] to assess the emotional response to the virtual touches in terms of experienced relaxation, happiness, desire, anxiety, disgust, and fear. The DEQ measures the intensity of several experienced emotions. It assesses each discrete emotion with four individual items (e.g., happiness: happy, satisfaction, enjoyment, liking). Participants had to indicate to what extent they experienced the corresponding feeling after each interaction scene, separated for initiated and received touches (scale from 1-7, "not at all"-"to some extent"-"extremely").

5.3.4 Internal Consistency of Measures. Most subscales yielded consistently acceptable α values greater than .66 or .80 (i.e., CIT, SSQ, NMMSP, Relaxation, Happiness, Anxiety, Disgust, Fear)[1]. The embodiment items' internal consistency was questionable when combined into one subscale (between .50 and .60). Nevertheless, as already stated, we intended to analyze the items on a per question basis. Cronbach's α values for desire were not consistently acceptable, as in two conditions, the value was between .50 and .60. We excluded the item "wanting" from this scale, resulting in α values above .8 in each condition.

6 RESULTS

First, we present the results of the analysis of the immersive experience. Second, we present the emotional experience's descriptive results, followed by an inferential analysis of the assumed effects of intimacy, touch direction, and sex. Third, we present results regarding the association between comfort with interpersonal touch and the emotional experience of received and initiated touch. All significance tests were conducted on a .05 significance level.

6.1 Immersive Experience

The high and low intimacy interaction scenes induced moderate to high perception of spatial presence and co-presence (Table 2). Two Wilcoxon signed-rank tests were calculated due to rejected normality assumption of the difference scores. The test did not reveal a significant difference in terms of spatial presence (Z = -.698, p = 0.485) or co-presence (Z = -1.662, p = .096).

On average, participants had a moderate perception that the avatar was their own body and felt that they were controlling it as it was their own. Correspondingly, they seem not to have had the feeling, that it was moving on its own. Due to rejected normality assumption of the difference scores, as well as to non-symmetric score distributions we calculated three exact sign tests that did not reveal a significant difference of median scores of the items between the two conditions: "my own body" exact binomial *p (2-tailed)* = 0.405, "control" exact binomial *p (2-tailed)* = 0.454, "on its own" exact binomial *p (2-tailed)* = 0.481.

[1]Please refer to the auxiliary material for exact α values for each subscale per condition

Table 2: Immersive experience during low and high intimacy interactions assessed on 7-point likert-scales.

	M(SD)	
	low	*high*
Presence		
Spatial Presence	5.49 (.864)	5.41 (.892)
Embodiment		
It felt like the avatar was my own body.	4.2 (1.59)	4.43 (1.59)
It felt like I could control it as if it was my own body.	5.34 (.963)	5.25 (.811)
It felt like it was moving on its own.	1.18 (1.06)	1.25 (1.08)
Social Presence		
Co-Presence	5.47 (1.04)	5.71 (.951)

No participant wanted to stop the experiment or mentioned impairments of well-being due to VR exposure. The mean total SSQ score is relatively low 31.79 (SD = 26.51), with 235.62 being the possible maximum score.

In conclusion, we retained the assumption that both conditions provided the same immersive experience and thus did not consider the immersive experience in the following analysis.

6.2 Emotional Experience

Figure 4 illustrates the emotional experience based on the DEQ scores. Mean and median values indicate that participants felt relaxation and happiness with moderate intensity, slight feelings of anxiety, and little to no desire, disgust, or fear. Thus, most participants' perceived emotional reaction was moderately intense at most and somewhat of positive valence. However, the individual observations illustrated in Figure 4 indicate partly substantial inter-individual differences between participants' emotional experiences. Reported relaxation and happiness scores range between low and very high values independent from intimacy or the direction of touch. Further, some participants experienced moderate anxiety levels during low intimacy touches, and high degrees of anxiety during high intimacy touches, independent from touch direction. Also, for the emotions desire, disgust, and fear, there are inter-individual differences with observations in the range of no to moderate intensity.

6.2.1 Influence of Intimacy, Involvement & Sex. Relaxation and happiness data met assumptions for parametric testing. Thus we conducted two 2(intimacy) x 2(direction) x 2(sex) repeated measures ANOVAs on the relaxation and happiness scores with intimacy and direction as within-subject factors and sex as a between-subject factor. Desire, anxiety, disgust, and fear data did not meet requirements

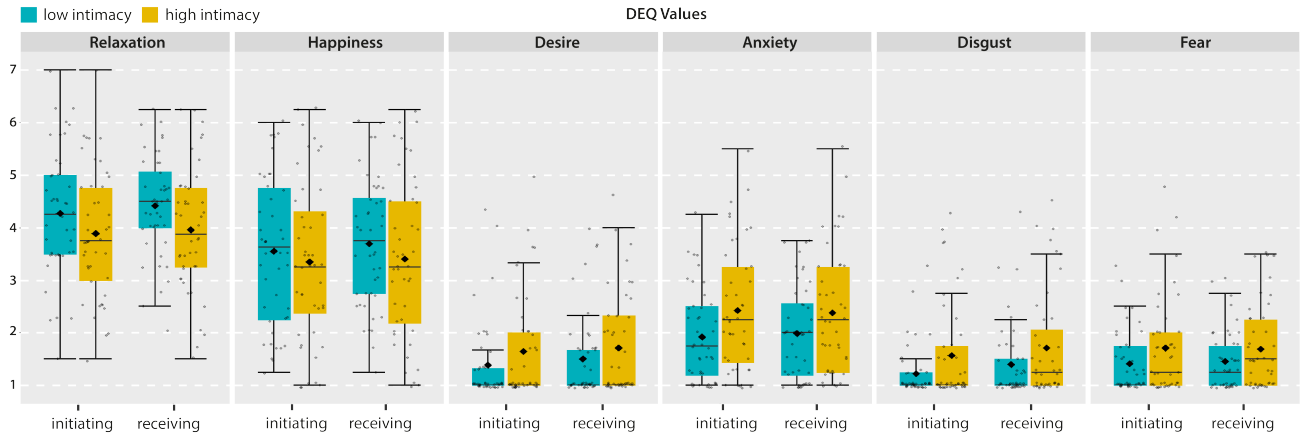


Figure 4: Boxplots with median, mean (diamond), interquartile distance (box), range (whiskers, excluding outliers) and individual observation values (gray points) for the DEQ subscales grouped by intimacy and touch direction. Assessed on 7-point likert-scale: 1(not at all) - 4(some extent) - 7(extremely)

Table 3: Main and interaction effects of intimacy, touch direction, and sex on DEQ scores.

ANOVA	Relaxation	Happiness	npar ANOVA	Desire	Anxiety	Disgust	Fear
Sex			**Sex**				
$F(1, 42)$	4.98	1.85	$F(1, \infty)$	5.38	3.54	2.48	7.08
p	**.031**	.182	p	**.020**	.060	.115	**.007**
$\omega\hat{2}$	.044	.010					
Intimacy			**Intimacy**				
$F(1, 42)$	9.37	6.57	$F(1, \infty)$	6.66	8.54	9.06	3.82
p	**.004**	**.014**	p	**.001**	**.003**	**.003**	.051
$\omega\hat{2}$	.036	.006					
Direction			**Direction**				
$F(1, 42)$	1.45	5.12	$F(1, \infty)$	3.47	.040	11.3	2.10
p	.235	**.029**	p	.062	.842	**<.001**	.148
$\omega\hat{2}$	.000	.001					
Sex x Int			**Sex x Int**				
$F(1, 42)$	.208	.492	$F(1, \infty)$	7.28	.311	2.06	.157
p	.651	.487	p	**.007**	.577	.151	.693
$\omega\hat{2}$	.000	.000					
Int x Dir			**Int x Dir**				
$F(1, 42)$	.209	.245	$F(1, \infty)$	.006	.283	.664	.575
p	.650	.623	p	.936	.594	.415	.448
$\omega\hat{2}$	.000	.000					
Sex x Dir			**Sex x Dir**				
$F(1, 42)$	.111	3.03	$F(1, \infty)$	.670	.200	.251	.238
p	.741	.089	p	.413	.654	.616	.625
$\omega\hat{2}$	.000	.000					
Sex x Int x Dir			**Sex x Int x Dir**				
$F(1, 42)$	.010	3.82	$F(1, \infty)$	.683	4.01	11.4	.054
p	.919	.057	p	.408	**.045**	**<.001**	.816
$\omega\hat{2}$	.000	.000					

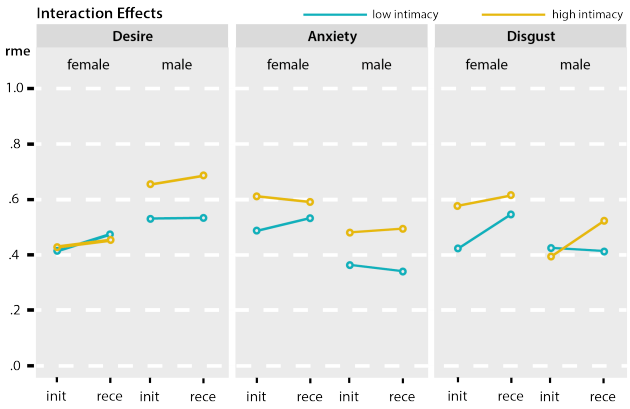


Figure 5: Profile plots of the relative marginal effects (rme) showing the detected interaction effects: Sex x Direction on desire, Sex x Intimacy x Direction on Anxiety and Disgust

for parametric testing (i.e., normality of residuals, symmetric distributions, no extreme outliers). Thus, we conducted a non-parametric factorial analysis of repeated measures data by using the *f1.ld.f2 function* from the *nparLD* R package [2] to test for main and interaction effects [11, 42].

We found significant main effects for sex and intimacy on relaxation, intimacy, and direction of touch on happiness, and sex on fear. Results are summarized in Table 3. Further, we found a second-order interaction effect of sex and intimacy on desire and third-order interaction effects of sex, intimacy, and direction of touch on anxiety and disgust. We did not further decompose detected second- and third-order interactions effects as this process would have required an extensive report of results. Alternatively, Figure 5 provides an intuitive assessment of how the individual factors have interacted. The non-parametric factorial analysis calculates the rme values (relative marginal effect) provided in Figure 5. They are interpreted as the probability that a randomly chosen observation from the whole dataset, has a smaller value than a randomly chosen observation from the subgroup of interest. Thus, it corresponds with the average scores reported by a subgroup (e.g., $rme_{\text{fear,male}}$ = .387 means: with an estimated probability of .387 a fear score randomly chosen from the whole dataset is smaller than a fear score randomly chosen from the scores reported by men)[42].

6.2.2 Relaxation. We found significant main effects for sex and intimacy on reported relaxation. Male participants were more relaxed (M = 4.54, SD = 1.16) than female participants (M = 3.88, SD = 1.09). However, participants reported higher intensity of relaxation for low intimacy touches (M = 4.35, SD = 1.09) than they did for high intimacy touches (M = 3.95, SD = 1.20). The effect sizes are small to medium (.01 < $\hat{\omega 2}$ < .06).

6.2.3 Happiness. We found significant main effects for touch direction and intimacy on reported happiness. Participants reported more happiness when they were touched (M = 3.55, SD = 1.39) than they did when they touched their partner (M = 3.45, SD = 1.46). Participants reported higher scores of happiness for low intimacy touches (M = 3.63, SD = 1.31) than for high intimacy touches (M = 3.38, SD = 1.53). The effect sizes are small ($\hat{\omega 2}$ < .01).

6.2.4 Desire. We found a second-order interaction effect of sex and intimacy on the perceived desire. Compared to women, men's perception of desire intensified with higher intimacy of touches. And women tended to report generally less desire than men (Figure 5).

6.2.5 Anxiety. We found a third-order interaction effect of sex, intimacy, and direction on the perceived anxiety. On average, men tended to report less anxiety than women. Thereby, for men and women, high intimacy touches induced more anxiety than low intimacy touches. However, for women, this effect of intimacy depended on the direction of touch. They felt more anxiety when they received low intimacy touches than when they initiated low intimacy touches. In contrast, their anxiety scores for received touches of high and low intimacy did differ only slightly. A slightly inverse interaction of intimacy and direction applies to men (Figure fig:profile).

6.2.6 Disgust. There was a third-order interaction effect of sex, intimacy, and direction on the perceived disgust. The sensation of disgust depended very much on the specific constellation of the three factors. Women reported more disgust while initiating intimate touches than for initiating low intimacy touches. For men, there was no difference between the two levels of intimacy for initiated touches. On the other hand, for women, intimacy seemed to make little difference when they were touched, as anxiety only differed slightly between high and low intimacy touches they received. For men, on the other hand, the sensation of disgust was more intensive while being touched with high intimacy (Figure 5).

6.2.7 Fear. There was a significant main effect for sex on reported fear. In general, female participants reported a greater amount of fear (*Mean Rank* = 100.97, *rme* = .571) than did male participants (*Mean Rank* = 68.69 *rme* = .387).

6.2.8 Comfort with Interpersonal Touch. We found positive associations between comfort with interpersonal touch and the happiness and relaxation experienced during intimate touches. Comfort with initiating touch was found to be strongly positively correlated with relaxation ($r(42)$ = .502, p < .001) and moderately with happiness induced by initiated intimate touches ($r(42)$ = .349, p = .020). Comfort with receiving touch was found to be strongly positively correlated with relaxation ($r(42)$ = .516, p < .001) and moderately with happiness induced by received intimate touches ($r(42)$ = .386, p = .010).

7 DISCUSSION

Our results show that virtual body contact can be a diverse emotional experience, and depending on individual differences, it can be quite intense or relatively shallow. Moreover, our inferential analysis revealed that the affective reaction was modulated by factors that are known to modulate unmediated social touch (i.e. intimacy, participants' sex, and the direction of touch). Further, the intensity of positive reactions was associated with the general individual

[2] https://rdrr.io/cran/nparLD/man/f1.ld.f1.html last access 20th of August 2020

comfort with interpersonal touch. In particular, intimacy and participants' sex modulated the emotional reaction.

In sum, the increased intimacy was associated with less favorable (relaxation, happiness) and stronger adverse reactions (anxiety, disgust, fear). Women tended to be stronger affected by this effect, partially also depending on whether they touched their partner or were touched by him. Interestingly, although men and women perceived only slight feelings of desire for low intimacy touches, men reacted to the intimate touches with an increase in perceived desire, whereas women did not. Our findings align with how social touch of varying intimacy between heterosexual opposite-sex strangers is perceived in the real world. That is, for women a touch must reflect the intimacy of the relationship to be appropriate and pleasant, whereas men are inclined to be more willing to tolerate intimate interaction with a stranger women [25, 54, 58].

Beyond contributing to research on mediated social touch by confirming previous work that virtual body contact can evoke reactions similar to its real-world counterpart, we contribute to this field in several ways. We assessed the affective reaction in terms of six different emotions, thus providing a nuanced look on different facets of the user experience beyond measures used in prior studies like pleasantness, appropriateness, erogeinity, and compliance [7, 14]. Thereby, our results show that virtual social touch can simultaneously evoke multiple emotions of varying valence. By investigating initiated and received touches in a single study, we acknowledged the bidirectional nature of social touch. Consequently, we identified interrelationships of touch direction with intimacy and sex [24].

Concerning older prior work, we contribute to the field by using a VR setup that equals consumer-level scenarios that, compared to other recent studies, utilized full-body motion tracking and user-representation in the context of virtual social touch. Further, our and recent related results [14] highlight, that it is also imperative to investigate mediated social body contact that is primarily induced by visual cues and does not rely on sophisticated haptic feedback devices.

Further, our results demonstrate that even in a prescribed, neutral situation, without provoking visual stimuli (like an avatar in underwear [14]), virtual social touch can, although with limited intensity, induce diverse emotional reactions.

Furthermore, our results inform previous studies on perceived humanness of agents, by motivating follow up studies to consider intimacy of touch as a parameter to increase perceived agent and avatar humanness [26] further.

We admit that the effects we detected and the reported intensities of emotional experiences are small and consider the study setting's following characteristics as a potential explanation. Our study scenario differed from the real world as participants could not speak with their interaction partners. Further, the avatars did not react with non-verbal social signals like changes in mimic to the touches, that could have affected emotional responses [10, 20]. However, by controlling these factors and controlling the course of the interaction by a prescribed procedure, our experimental scenario lacked the spontaneous nature of real-world social interactions. Correspondingly, we assume that the limited available communication channels and the prescribed course of interaction may have limited the intensities of emotional reactions and the effects of the identified influencing factors. On the other hand, this interpretation leads to the assumption that in a spontaneous virtual social interaction, in which the users may be more personally involved, the emotional reactions may be of higher intensity.

Moreover, as we applied subjective measures in retrospect, it is, of course, possible that the participants' spontaneous emotional reaction intensity was no longer salient. Also, the majority of participants had few or no prior VR experiences. As participants may have been overwhelmed by the novel experience in general, a potentially more substantial effect of the touches could have been masked.

7.1 Limitations

Our results have to be interpreted with the following limitations in mind. We have combined three forms of interaction in one of two groups and have not evaluated them individually. Of course, this means that information was lost. Perhaps the individual interactions within each group could have had opposing effects on the experience based on the degree of intimacy the participants associated with the individual touches.

The emotional evaluation of the received touches could have been confounded by the touch's limited visual stimuli (due to the headset's limited field of view) [32]. In particular, during the hug interaction, we assume that the emotional reaction probably was affected by the invasion of the participants' personal space, which also applies to virtual social interaction [39, 63].

Further, based on the interpretation that virtual social touch shares influence factors with its unmediated counterpart, there are numerous potentially confounding factors that we did not control for in this specific study, but that influence social interaction in the real world. These include implicit social biases concerning individual assumptions about others and stereotypes towards in-group members and against out-group members [17, 35]. We assume that such biases and aspects related to the perceivable traits of the interaction partner (e.g., the body height and perceived attractiveness of the interaction partner) contribute to the large inter-individual differences in the emotional evaluation we found. However, this assumption is still in line with our general interpretation. That is, virtual social touch can evoke different emotional responses moderated by factors that do also moderate the perception of unmediated social interaction.

Another limitation relates to the limited avatar individualization possibilities that did not allow participants to create a precise virtual representation. Thus, based on the Proteus effect [64] the avatar's identity cues that are not shared with the user's visual appearance that embodies it may have affected the touching behavior, attitudes, and experiences. For example, the perceived attractiveness of their avatar may have affected their acceptance of intimate behavior [64]. This potential confounding effect indicates that virtual social touch is also affected by effects exclusive to virtual interaction.

Given these limitations, we highlight, that our results regarding the valence and intensity of emotional responses are not readily transferable to any social interaction context or user constellation in virtual worlds beyond the characteristics of our study

(i.e., prescribed touches, virtual interaction between heterosexual, opposite-sex strangers represented by realistic avatars with limited non-verbal communication cues, the interaction between avatars of white skin-tone, citizens of Central Europe)

7.2 Future Work

The limitations above translate directly into follow up research questions and study designs. For example, a nuanced comparison of specific touch interactions regarding their impact on users should lead to more specific design recommendations for VR content creators, by answering what touch-types may be adequate for specific social mechanics. Thereby, we suggest considering more diverse constellations of participant and avatar characteristics in follow up studies. This would aid content creators to understand under which conditions specific social norms from the physical world are relevant in the virtual realm and when virtual interaction underlies its own rules (e.g., the impact of the sexual orientation of participants, implicit social biases, the quality of the interpersonal relationship, different cultural backgrounds, Proteus effect).

Another question which emerges from our sample characteristics relates to the impact of potential familiarization effects, i.e., does prior VR experiences affect the perception of virtual social body contact? We consider field studies within the current social VR platforms (online questionnaires or interviews with users) as an appropriate method to answer this question. This approach could also be valuable to evaluate social touch that occurs during spontaneous virtual interaction.

Concerning the Proteus effect, we note that some social VR applications feature unlimited avatar customization options (e.g., non-humanoid avatars, excessively large or small avatars). Consequently, we consider the investigation of how appearance characteristics that do not apply to humans and social interaction outside of VR affect the experience of virtual social touch as an exciting field of research. In that sense, we currently focus on fostering desired and inhibit undesired experiences of virtual body contact based on variations of immersive characteristics of the interaction. Inspired by the idea to augment the social interaction in VR [45], we currently prepare a study on visual augmentations of virtual touches (e.g., particle effects on body contact) to manipulate emotional reactions.

7.3 Practical Implications

Our results inform practitioners about how they may implement mechanics related to virtual body contact in social VR. Our findings suggest that virtual social touch should be a moderated feature to induce desired but simultaneously limit negative emotional experiences during spontaneous encounters between strangers in social VR. Our results related to the negative emotions emphasize that virtual physical harassment [5] can have real emotional consequences. The large interindividual differences imply that there could always be individuals who are particularly sensitive to experiences in VR. Thus, developers should provide the user with adjustable privacy settings related to social touch capabilities. It is already common practice in social VR applications that users can configure a personal space bubble that prevents others from invading one's personal space. We think a natural extension of such a system would allow users to configure what types of touches they may allow with other users in specific contexts. Such a system could also be pre-configured automatically based on intraindividual personality characteristics (e.g., comfort with interpersonal touch)

Another value of the present results relates to the design of social features tied to virtual social touch. As an example, friending in *Recroom* can be triggered by a handshake, what we would consider as an adequate interaction metaphor. In contrast, touching another avatar's pubic area for 20 seconds to send a friend request probably would be entirely inappropriate. This intentionally exaggerated example should clarify that the use of certain touch interactions for social VR features should always correspond to the social feature's underlying meaning. At the very least, the design of such interactions should always consider how these interactions are evaluated outside of VR and that they should not be mandatory for users to interact in the virtual world.

8 CONCLUSION

We investigated virtual social touch in a two-user VR scenario and found that it affects diverse emotions. Our results indicate that corresponding to unmediated social touch, touch intimacy, the direction of touch, and participants' sex modulate positive and negative affective responses to virtual touch. Thus, VR can induce meaningful interaction based on interpersonal touch, which resembles its unmediated counterpart in terms of applied norms and affective responses, even without realistic haptic feedback. To inform future research and practitioners, we indicated practical approaches for follow up studies and derived implications for the use of interpersonal touch in social VR applications. Eventually, a precise understanding of the aspects that shape our experience of virtual social interaction not only opens up the possibility to bring compelling emotional experiences to people who are physically separated from each other. It also enables us to develop mechanics that foster desired and prevent undesirable experiences induced by virtual social interactions.

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A.2. The Most Social Platform Ever? A Survey about Activities & Motives of Social VR Users

Attached is the accepted author's version of the publication:

P. Sykownik, L. Graf, C. Zils and M. Masuch, "The Most Social Platform Ever? A Survey about Activities & Motives of Social VR Users," 2021 IEEE Virtual Reality and 3D User Interfaces (VR), Lisboa, Portugal, 2021, pp. 546-554, doi: 10.1109/VR50410.2021.00079.

The Most Social Platform Ever? A Survey about Activities & Motives of Social VR Users

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ABSTRACT

We present online survey results on social virtual reality (social VR) users' activities and usage motives. Based on content analysis of users' free-text responses, we found that most users, in fact, use these applications for social activities and to satisfy diverse social needs. The second most frequently mentioned categories of activities and motives relate to experiential aspects such as entertainment activities. Another important category of motives, which has only recently been described in related work, relates to the self, such as personal growth. Our results indicate that while social VR provides a superior social experience than traditional digital social spaces, like games or social media, users still desire better and affordable tracking technology, increased sensory immersion, and further improvement concerning social features. These findings complement related work as they come from a comparatively large sample (N= 273) and summarize a general user view on social VR. Besides confirming an intuitive assumption, they help identify use cases and opportunities for further research on social VR.

Keywords: Social VR, online social worlds, user motives, virtual reality.

Index Terms: Human-centered computing—Empirical studies in collaborative and social computing; Human-centered computing—Virtual reality

1 INTRODUCTION

Social VR refers to an emerging ecology of applications that enable geographically remote users to interact with each other in shared virtual environments through VR technology, i.e., immersive head-mounted displays. In the shared virtual space, users are usually represented by avatars they control with their body-movement due to tracking technology [28, 29, 32]. Many social VR applications emerged since 2015 (e.g., *Altspace VR, High Fidelity, Anyland, VRChat, Facebook Horizon*), and especially the announcement of *Facebook Horizon* in 2019, which is currently in beta status (late 2020), indicates that social VR is meant to stay and potentially reshape the ways we interact with remote others. As *Facebook*'s CEO Mark Zuckerberg stated in an interview in 2016 after the company acquired *Oculus*[1], VR is going to be the most social platform that has ever existed. Correspondingly, previous studies indicate, current social VR applications are, in particular, characterized by a variety of experiences comparable to face-to-face interactions in terms of verbal and especially non-verbal expression capabilities, as well as the variety of mediated group and intimate activities they offer [22, 25, 28–30, 43]. Further, in times of limited opportunities for real-world social interaction (as in the ongoing COVID-19 pandemic), as well as use cases where individual people may not be capable of engaging in physical social interaction, social VR's promise is the access to authentic and meaningful social interactions over distance [22, 43].

Although the body of literature on social VR is steadily growing, it is still unclear what values these applications offer for most users in their day-to-day life. Previous work focused mainly on a systematic description of how these applications' specific features are designed to afford sociality. It thereby often adopted the perspective of social VR designers or industry experts [20, 28] and systematically compared different applications regarding the specific features they offer [29, 41]. A series of qualitative studies were published recently that provide a user-focused perspective on specific topics related to social VR. These topics include long-distance relationships, anonymity, cross-generational interaction, non-verbal communication, and avatars [11, 12, 22–26, 43]. In particular, one of these publications is concerned with offering empirical evidence on what users are generally doing in social VR and why their social VR activities are meaningful to them, without focusing on a specific contextual frame [22]. While the authors identified exciting insights into what makes social VR meaningful for individual users, their results are only based on comparatively small samples (N = 30), as they conducted in-depth interviews. Hence, even if the authors could collect some exciting individual cases, the current literature body still lacks comprehensive empirical evidence about the users' activities and their motives to use social VR. Furthermore, the currently available findings provide little information about the relative importance of individual activities and user motives compared to each other. Our work, therefore, integrates seamlessly into these interview studies and addresses the following four research questions:

- What are users doing in their favorite social VR applications?
- What are the motives that drive their social VR usage?
- What makes social VR superior to other digital social places?
- What do they want to be improved in the future?

Although we are not the first to deal with these questions, we contribute to further developing the domain by expanding previous research by conducting a large-sample online study with social VR users. In particular, our work can be seen as a natural extension of earlier interview surveys. As already noted by other researchers in this field, a thorough look at these questions helps identify research and development opportunities by indicating what features of social VR are currently valuable for users but may be improved in the future or features that are not yet considered in research. Further, as the way we present our results in this paper cannot do justice to the level of detail of many of the answers we received, we also share the collected raw data with the research community[2]. Eventually, a precise understanding of the "What" and "Why" of social VR usage empowers us to create compelling social experiences for physically apart people.

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[1] 29th August 2016; Link to Video on Facebook

[2] Link to the OSF project repository

2 Related Work on Social VR

Social VR applications are rooted in the domain of collaborative virtual environments [4], which have a long history in HCI research and for which there are diverse research areas such as experiential differences to face-to-face interaction [1], collaboration techniques [44], proxemics [2], interpersonal touch [3], or collaborative learning [35]. Although social VR is still an emerging consumer application genre, the current literature on this subject is already diverse. It includes empirical work based on the evaluation of multi-user VR prototypes to investigate specific questions in laboratory studies (e.g., [10, 14, 17, 40]). Further, an increasing body of theoretical literature aims to systematize the landscape of social VR design practices (e.g., [17, 29, 41]). These are complemented by interview and observational studies that investigate user-behavior in commercial social VR applications, for example, in the context of harassment [5], self-disclosure [26], and interactions between different age groups [23, 24].

Research concerned with current social VR applications' design practices found different strategies designers employ to shape their platforms' social experience. These strategies refer, for example, to the aesthetics and architecture of virtual places, mechanics that promote the definition and adhering to social norms, and communicative affordances related to the avatars [28]. In particular, it was found that the specifics of a platform's avatar system are, in many ways, tied to the social experience. For example, avatar locomotion and personal space mechanisms determine how fast and close users can approach each other [20]. Further, a feature comparison of several social VR applications found that despite the potential to induce authentic social experiences, there are still many open challenges and opportunities for designing and utilizing expressive non-verbal communication features [41]. Overall, the literature on design practices concludes that there are still many challenges and unused potentials that need to be addressed by practitioners and researchers alike.

However, the body of literature indicates that social VR seems to extend the social and experiential qualities of traditional shared virtual spaces due to its technological characteristics that induce a strong illusion of virtual body ownership over virtual user representations [16, 19, 27, 38] and a feeling of actually being present in the shared virtual worlds [37, 42]. More specifically, VR-mediated social interactions support verbal and non-verbal communication cues and provide experiences similar to face-to-face interaction [9,21,25,30,39]. The combination of motion-tracking and embodied virtual representations allows users to utilize non-verbal communication cues to support communication and interaction initiation and affords feelings of privacy and social comfort during interactions with strangers while still offering an authentic social experience [25]. Social VR was also found to be of value in intimate social interaction contexts like long-distance relationships. It provides a sense of physical closeness and social presence and supports the replication and sharing of mundane real-life activities, which are essential in such contexts [22, 43]. Further, as social VR extends the experiential quality of creating and using avatars, social VR avatars are a more engaging means for self-expression and identity exploration than in traditional digital social spaces. [11, 12].

Regarding what people generally do in social VR and why they appreciate it, it seems to provide similar but extended opportunities for social connectivity, self-reflective processes, and meaningful experiences compared to traditional digital social spaces [22]. More specifically, social VR users value five types of meaningful activities: activities that utilize the full-body tracking capacities of current VR technology (e.g., non-verbal communication, dancing), mundane everyday activities (e.g., sleeping), activities for mental self-improvement (e.g., improving social skills), cultural appreciation and educational activities (e.g., learning a language), and participation in immersive events (e.g., group meditation) [22]. However, previous work also identified three specific design recommendations for further support and improvement of these activities: improvement of social connectivity, integration of communication affordances in and out of VR, increasing realism and naturalness [22].

Based on this literature review, social VR seems to support general, and intimate socializing, self-expression and identity exploration, self-improvement and mental health, and learning skills and cultures [11, 22, 43]. However, these results are predominantly based on a series of interview studies with comparatively few participants (N = 30). While providing interesting detailed insights, they should not be generalized without further investigation. Furthermore, the currently available findings provide little information about the relative importance of individual activities and user motives when compared to each other. This can be explained by the corresponding literature's qualitative approach, which aimed to reveal individual topics rather than compare them in quantified terms. Therefore, we would like to add to the literature on social VR a more comprehensive view of user activities and motives that assess individual aspects' relative importance based on how many users report them.

3 Method

We conducted an online study between May and June 2020 and recruited participants via posts in nine subreddits[3] related to VR, social VR, and specific social VR applications: *VRchat, RecRoom, AltspaceVR, Bigscreen, SocialVR, FacebookHorizon, NeosVR, virtualreality*. Additionally, we posted the study on a message board of a german digital meetup space dedicated to VR a few days after this community organized a virtual event on the topic social VR[4]. After one week of operation, we also posted updated calls in the bigger subreddits, as older posts that no longer attract attention are less visible for the community. We thereby shared already collected statistics on survey completion rate, social VR usage history and frequency, and the favorite platforms so far to gain more attention. In the posts, we linked the actual online survey, for which we used a custom installation of the survey application *Lime Survey*. We stopped the survey when there was no new participation for several days. Overall, 273 persons participated in the online survey. There was no compensation for participation.

3.1 Research Framework

We applied the Uses and Gratifications Theory (UGT) as a framework for our work, which has its origins in the 1940s in the context of empirical mass communication research and aims to identify media usage motives [6].

This theory's particularity is the assumption of active and self-reflective media users, which, due to personal needs, consciously control their media usage behaviors and aim to use those media that they expect to meet their needs [6, 18]. Despite recurrent criticism of the theory, it is an established, however evolving, approach for understanding media use [34] and is still applied in diverse technological contexts such as social media [31], social virtual worlds [13], video game streams [36], or augmented reality games [8]. An early summarizing categorization of user needs satisfied by general media use included cognitive, affective, personal integrative, social integrative, and tension release needs [18]. Recent research applying UGT reveals a broad spectrum of needs that often offer a more nuanced perspective on the correspondingly studied applications while roughly falling into the early five categories. It is thus equally common for studies that apply UGT to either re-use previously identified categories (e.g., [15, 31, 36]), or to use open-ended questions for exploratory analysis to identify novel types of needs and user motivations (e.g., [15, 31, 46]).

[3] Link to reddit.com

[4] Link to Virtual and Augmented Reality Frankfurt

3.2 Assessed Data & Measures

The online survey included the question areas social VR usage behavior (custom items), activities and motives (open-ended and questionnaire), perceived benefits of social VR (open-ended), wanted features for social VR (open-ended), perceived social closeness compared to other platforms (custom items), and demographics[5]. As part of a more comprehensive research question, personality traits have also been recorded with the 10-items Big-Five Inventory [33], but are not addressed in this paper.

At the core of the survey were the questions assessing user activities and motives. As social VR is still a comparatively novel application type, we wanted the participants to articulate their thoughts freely. Thus, we decided to use open-ended questions instead of pre-defined items, which they would then have to agree or disagree. We assessed activities with the question *"... we would like to know which of the various activities offered by your favorite* [social VR] *app you use the most. In other words: For what do you use your favorite social VR app?*". Motives were assessed with the question *"...if you could tell us your reasons and motives for using your favorite social VR app. In other words: Why do you use it? So ask yourself what value the application has for you as a person"*. In addition to these open questions, we have included the User Motivation Inventory (UMI) [7] to determine the degree of motivation internalization of the participants, i.a. if their engagement in social VR is motivated by extrinsic motivation, or intrinsic motivation and whether it can be assumed that they will continue to use it. The UMI consists of six subscales and, in sum, 18 items and assesses amotivation, external, introjected, identified, and integrated motivation regulation, and intrinsic motivation (7-point Likert scale ranging from strongly disagree to strongly agree). The activities, motives, and UMI questions referred to the participants' favorite social VR apps.

Perceived benefits of social VR compared to other, non-VR social applications like online multiplayer games or social media and wanted features for social VR were assessed with open-ended questions.

To get a statement about the social experience in social VR from all participants we further asked them in how far they experience a social closeness in social VR they can not or do not want to experience in real life and other social applications (7-point lLkert scale ranging from strongly disagree to strongly agree).

The benefits, wanted features, and social closeness features did refer to social VR in general.

3.3 Content Analysis

The first three authors performed an iterative content analysis of the answers to each of the open questions. The analysis goal was an agreement on the definition of clusters of categories to which each answer can be assigned. Thereby, we sought agreement by engaging in informal discussions that followed the answer coding steps. To reduce the impact of individual researcher bias while including diverse perspectives, we started each analysis by reviewing answers independently from each other. The result of this first step was a collection of rough categories from each researcher that we then discussed together in order to craft a shared codebook for the next iteration. Subsequently, we coded the answers independently from each other based on the shared codebook. We again discussed the results and identified the remaining interpretation differences of the shared codebook. Eventually, after agreeing on the derived categories, the first author coded all answers to derive a definite quantification of the identified main and subcategories.

Concerning the question that assessed user motives, we decided to guide the analysis process by applying the categories of *Functional, Social*, and *Experiential* needs that were identified in the literature as being relevant for the engagement with the virtual social world game *Second Life* [45,46] and which we expected to be relevant in social VR as well. For all answers and partial answers that did not fit into these categories, we first created our own categories that we added to the shared codebook after finding agreement.

[5]The survey is included in the supplemental material of this paper

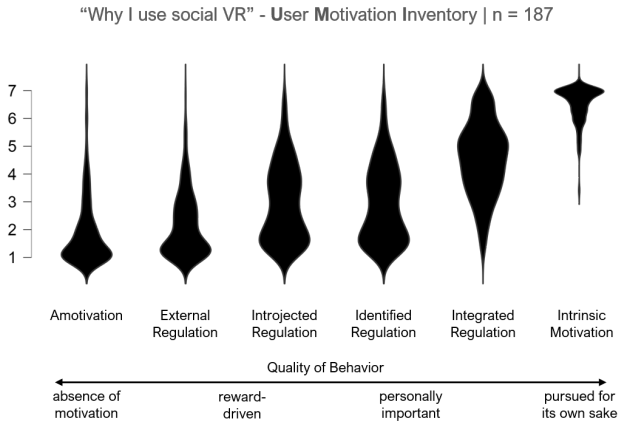

Figure 1: Violin plots presenting the distribution of UMI subscale scores. Higher scores correspond to a stronger agreement. Quality of behavior continuum indicates how self-determined social VR usage is.

4 Results

From 273 participants, we collected 174 complete and 99 incomplete datasets. To use as much of the data as possible, we included all available valid data relevant to the respective analyses. Thus, in the following, the n-values indicate the valid datasets that entered each analysis. Figure 2 provides an overview of the sample characteristics based on social VR usage habits and gender, geographical region, and occupational status. In summary, most participants who provided the information were male, lived in North America, and were employed or studying in some way at the time of the survey. Most of them were between 20 and 30 years old ($M = 23.6$, $SD = 8.74$, n = 172). Participants were engaged in social VR for 2.77 years on average ($SD = 1.35$, n = 265), whereby half of them (55.7%, n = 262) were using it daily at the time of the survey. The majority of participants indicated *VR Chat* as their favorite social VR app (64.4% of those who indicated n = 258), followed by *RecRoom* (15.9%), *Neos VR*, *BigScreen*, and *Altspace VR* (each less than 10%). Five other applications were also specified once and summarized in a category *Other*.

4.1 Intrinsic Motivation & Social Closeness

Figure 1 illustrates UMI results, which indicate that the majority of participants use social VR out of intrinsic motivation or at least based on integrated regulation (i.a., because social VR usage is congruent with their personally endorsed values [7]).

From 177 participants, 75% indicated an agreement of at least 5 with the statement that they would experience a social closeness in social VR that they can not or do not want to experience in other social applications ($Mdn = 6$). Similarly, 75% indicated an agreement of 4 or higher with the statement that they would experience a social closeness in social VR that they can not or do not want to experience in real life ($Mdn = 5$).

4.2 User Activities in Social VR

We identified three main types of activities that users reported to do most often in social VR: *Socializing*, *Entertainment*, and *Learning*

Figure 2: Summary of sample information and content-analysis results. *Sample information*: The missing values indicate how many participants have discontinued the survey. *Content-Analysis*: Bar charts show the number of answers associated with the main categories. Lollipop charts show the number of answers associated with the subcategories for the most frequent main categories. n-Values indicate the number of valid answers that were included in each analysis. The motive chart shows subcategories for all main categories due to the focus on the motives in this paper.

& Working. As Figure 2 illustrates, most users engage in socializing and entertainment activities, whereas only four reported that they engage in learning or working activities (e.g., learn sign language, doing light work by streaming external media into social VR). Further, we identified subcategories of the socializing and entertainment activities that are also illustrated in Figure 2, which we briefly describe in the following.

4.2.1 Socializing Activities

In the *Socializing* category, we included answers that either explicitly referred to variations of the term "socializing", described how they found friends in social VR or specified the act or social context of interactions. In fact, most participants did not specify exactly in what ways they socialize with others in social VR, e.g., *"Well, VRChat is a social interaction platform so I'm using it for that purpose"*(m19). However, if they did, they most often mentioned that having conversations with others, e.g., chatting or talking to others, is what they mainly do in social VR or spend time with others without a specific purpose (e.g., hanging out, chilling). Few participants engage in more intimate social contexts like interactions with significant others, dating, or erotic role play. Many participants also specified with whom they interact socially. 70 users interact with known others (e.g., friends, family, relatives), and 49 users indicated to purposefully seek contact with strangers to make new contacts and friends.

4.2.2 Entertainment Activities

In the *Entertainment* category, we included answers that described activities like gaming (i.a., PvP, board games, user-created), content creation (i.a., environments, games, avatars), and exploration (i.a., built-in worlds, user creations), watching video content, partying and dancing, listening to music, participating in community events (talks, discussions), engaging in role-play (not erotic role play), or simply enjoying to observe others. The most popular entertainment activities were playing games and creating content. Notably, many of the entertainment activities are shared with others. They thus also have a social component (68 mentions): *"I get together with friends and new people and watch shows together."* (m46), *"Mainly just finding areas to explore together with other people"* (m19), *"I like to draw people's avatars in the presentation room of VRChat to make them happy"*(f19), *"... I just talk with people and listen to music just like in a house party"* (m29), *"there is also a fantastic dancing, drinking, and partying community"* (f27).

4.3 Social VR User Motives

We identified four main types of motives or needs that users referred to when explaining their engagement with their favorite social VR application: the categories taken from the literature *Social*, *Experiential*, and *Functional* needs, and additionally needs related to the *Self*. As Figure 2 illustrates, most users referred to social motives and needs, followed by half of them referring to experiential reasons. Almost 25% indicated reasons that are personal and self-related. Functional reasons were the least common. In the following, we describe each category in more detail by addressing its subcategories that are also summarized in Figure 2.

4.3.1 Social Motives

This category refers to the social needs addressed by or the social benefits that result from establishing and maintaining interaction with other users. As Figure 2 illustrates, social VR engagement is based on diverse social needs, ranging from a desire to perceive the presence of others to establish meaningful relationships and finding a substitution for real-world social interactions.

The most common social motive described by the participants is a desire to come and stay in contact with other people: *"I use my favorite social VR app to speak with both friends I have made through it and to perhaps befriend others"*(m21).

The second most common subcategory of social motives summarizes answers that emphasized the degree of social presence provided by VR technology and that it satisfies their need to socialize when explaining why they engage in social VR: *"It also helps giving a more physical presence to the people I talk to which gives everything a more genuine feeling"*(m24), *"I use it to gain the social interaction I need"*(f22).

For several participants, the engagement in social VR serves as a valuable substitution for real-world social interactions. Their answers often indicate that circumstances over which they have no or limited control restrict their opportunities to engage in real-world social interactions: *"Being someone who is very social, but doesn't always have the luxury to be able to go outside and meet people a lot, it helps me to find people to talk to ..."*(m32). Notably, several participants emphasized that social VR was their major or only access to social interactions due to local COVID-19 pandemic measures: *"No reason other than to try to keep social during the COVID-19 lockdown"*(m36), *"It's especially nice during quarantine to get to talk to others while feeling like you're really in the world there with them"*(fn/A).

Almost the same amount of users indicated that their main motive to use social VR is to diversify their social contacts. Thereby, they i.a. appreciated the access to people from all over the world and thus, different cultures, or to break through their personal social bubble: *"I like to use VRchat most to make new friends that I could never meet in my normal life, because I think it's important to get as many different perspectives about the world as you can and in VRchat it's easier to do than in the real world"*(m22), *"... Keeps my social circle from becoming an echo chamber"*(f24).

Another social need that users satisfy by engaging in social VR is the desire to find like-minded people: *"I rarely meet someone where I live that is into the same things. Therefore, I turn to VRChat on the weekends to give me that bar experience and socializing with people that are like me"*(f30).

A few users search for or found meaningful social relationships or assume that social VR supports in establishing those more intimate connections: *"[I] Met my significant other in-game."* (f33), *"Social, emotional, and romantic fulfillment"*(f23), *"I feel that this allows for closer bonds to form and lets you get to know someone a little better"*(f27).

4.3.2 Experiential Motives

This category refers to needs that are addressed and benefits that arise from the sole experience of social VR usage and includes benefits such as entertainment, excitement, playfulness, and escapism. Thus, users referring to an experiential motivation often experience pleasure and enjoyment while exploring the virtual world and engaging in the various activities it provides.

The most common theme of answers in this category was the seeking and appreciation of enjoyable experiences to pastime and for entertainment: *"I use it to have fun"*(m16), *"I just like to play VRChat. I don't have anything that motivates me besides that"*(m19), *"Boredom"*(n/A).

The second most common group of answers share the desire for some sort of escapism, or variety from everyday life, i.a., to relax (*"It is a relaxing escape. ... a good way to reduce stress*" (m57)), flee from specific real-world problems (*"I use it to escape reality. The real world can be stressful and it's nice to be able to have a second life in VR ..."*(m29)), to get access to activities during the COVID-19 lockdown (*"Especially due to Corona virus making things hard to actively go outside and interact with others, VR had made absolute turn around for that"*(f20)).

Social VR was also described as a creational outlet that offers opportunities for creating content and engaging in cognitive stimu-

lating activities *"... because of the insanely complex toolset it offers, allowing you to program stuff into your avatars or worlds with node based programming ..."* (m18), *"... I create work that I like, and it is nice to see others like my work too"*(m29).

Another source of experiential benefits is the satisfaction of curiosity that some participants stated to find in exploring community-created or other content: *"... I also enjoy meeting other talented people and seeing what they can do musically, artistically and 3D modeling wise ..."*(m32), *"The openness of creativity. Very little is limited and it's always interesting to see what people will make next"*(m25).

Only few answers describe that social VR is a source of gratification that emerges from overcoming challenges and induces feelings of competence: *"I consider it more meaningful to compete against other players ..."*(m48), *"I like playing rec room because I'm good at it, I'm quite insecure so it's nice seeing you are good at something"*(f17).

4.3.3 Self-Related Motives

We have identified a group of answers that describe benefits for personal identity, mental health, and personal development and thus refer to motives and needs related to the *Self*.

The most common self-related benefit users described was the support of emotional and physiological well-being: *"... VRChat is also therapeutic in many ways. Whether it is to help my meditation, soul-searching, healing, self-reflection or to help aid others in growing into their true, genuine identities, I use VRChat as a way to communicate more than just words."* (o22), *"It makes me feel less lonely"* (m16), *"... This game has especially kept me sane during the lockdown here in the UK"*(m23).

Several users emphasized that they use social VR because it allows them to express themselves freely in a way they want, be it in terms of role-playing or sharing aspects of them that they usually do not share with others in real life. A nuance of these answers was the appreciation of versatile customization possibilities and the anonymity that avatars provide: *"... playing it is the first time that I've really felt free to really express myself and be me without the weight of the real world and all the expectations that go with it."* (m22), *"... have fun expressing myself in crazy fun ways."*(f20), *"Because I can use avatars that better express who I want to be I find myself open in telling people about what I like and who I am as a person"*(m32).

A reoccurring theme was the notion of having problems with social interactions in the real world (specified or unspecified). Users whose answers we associated with this category described that in social VR they suffer less from the problems with social interactions they have in the real world or that social VR would help them to overcome these problems and improve their social skills: *"I'm alone at home and kind of socially anxious. Having an avatar is helping me feel less anxious about speaking with people and helps me talk more."* (m24), *"I think I use it to fulfill my need for closeness and socialization with people, something that I struggle with in real life."* (f19), or *"It also has helped me improve my ability to talk to people and get over some anxiety"* (f14).

Another self-related motive or benefit was the ambition or observation to grow as a person and expand one's horizons: *"It has been a continual source of inspiration, and joy that has me learning, and growing by the day, enriching my lives in numerous ways"*(o27), *"This app has value to me because it's a way for me to learn new things and expand my horizons"*(f14).

4.3.4 Functional Motives

This category refers to purposeful, task-related benefits derived from the completion of previously defined tasks. It includes the acquisition of specific skills and knowledge that are relevant outside of Social VR: *"I use it ... as a platform to learn new skills like 3D modeling and game programming with."*(m31), *"... learning about different parts of the world first hand from the people who live there also has its value to me."* (m22).

Another functional value that some participants described is the convenience that social VR affords to engage in certain activities: *"VR gives me an easy way to do that."* (m46), *"... I'm a pretty sociable person irl, but I vastly prefer VR since it is convenient ..."*(f22).

Two participants mentioned to use Social VR as a tool and a means to an end for which they otherwise do not have or want to spend the resources to fulfill it: *"... watching a movie in 3d or 2d on a huge screen while actually sitting in a small room is a huge feat in itself."* (m31).

4.4 Perceived Benefits of Social VR

Participants indicated four areas of benefits that social VR provides for social interaction that other social applications like online games or social media do not (see Figure 2).

The most frequently mentioned benefit is the *immersive experience* that social VR offers. This benefit category is based on the increased communicative expressiveness and interactivity with the virtual environment and others due to motion and position tracking and the degree of spatial and social presence that modern immersive VR technology induces (feeling like actually being there together).

The second most frequently mentioned advantage of social VR is an overall *better quality of the social experience*, which participants often referred to as being more authentic and natural in terms of, for example, others' behavior. Further, answers associated with this benefit category characterize the social encounters in social VR as more meaningful, intimate, and memorable. Furthermore, participants referring to the social experience perceive the social interaction atmosphere as healthier, more joyful, more effective, and more positive.

31 participants referred to *application-specific features* as beneficial for social interaction in social VR and thus did not directly refer to general social VR characteristics. For example, these participants emphasized that social VR applications are often specifically tailored and focused around social interactions and do not require them to engage in other goal-oriented activities, like online multiplayer games (More details are included in the supplemental material of this paper).

Another main category of perceived benefits is a perceived *increased accessibility and inclusiveness* that social VR grants to certain user groups. For example, these answers relate to the non-verbal communication capabilities of VR technology, which allow people to engage with others without relying on voice or text input. Another aspect that some participants highlighted was the combination of anonymity and realistic social interaction to establish a secure social interaction space for people who may suffer from social anxiety.

4.5 Wanted Features for Social VR

Participants indicated seven areas of features that they would like to be improved or implemented into social VR in the future (Figure 2). With mentions in over 20% of all responses, features related to the *Immersion*, the *Social* experience, and *Basic User Experience* are the most requested.

To increase *Immersion* the users wish to support more affordable and more extensive tracking technologies (e.g., face, eyes, hands) and the integration of more senses into the experience, particularly the development and support of haptic in and output devices.

The desired *Social* features relate to communication versatility (e.g., improvement of group conversation, direct messaging in and out VR, emoticons), convenient contact management (e.g., filtered user groups), diversification of group activities (e.g., friend & family features, more concurrent users) and implementation of security & safety mechanics (e.g., social moderation).

Social VR should also be improved in terms of the *Basic User Experience*. In particular, the participants refer to fundamentally functional aspects such as better performance (e.g., networking, fewer bugs) and usability issues with the user interface (e.g., limited or no customization of UI) and locomotion in VR. Overall, participants want social VR to be a way more seamless experience.

Another area of requested improvements relates to *Content Creation* features, which participants want to be more adaptable and easily accessible in general and best built into their favorite social VR application. They also mentioned particular features that would support content creation like integrating 3D volumetric live capturing of real-world objects.

Concerning *Avatars*, there seems to be a desire for more versatile design possibilities. For example, designing virtual clothes, non-human avatars, or expressiveness features were mentioned. Further, cross-platform avatars or avatars congruent to one's physical appearance are desired features.

Few participants would like to see easier and broader *Access* to VR technology in general (e.g., lower prices, more users) but also better user *Onboarding* within specific social VR applications by improving user onboarding processes and platform documentation.

Some participants expressed a desire for *Cross-Technology* integration features (e.g., communication between AR, VR, and non-immersive platforms) that would allow connecting with even more people. There should also be more versatile possibilities to transfer content from social VR to other applications and vice versa. Similarly, social VR applications should be integrated with the real world to blur the boundaries between virtual and real world.

Additionally, we identified 25 answers that could not be assigned to a unifying parent category and are clustered as *Diverse*.

5 Discussion

Based on the provocative statement that VR will be the most social platform ever, we have explored what social VR users mainly do on their favorite platforms, what benefits they get from it, what advantages they see in this new type of application, and which aspects should be improved in the future. Our online survey results indicate that social VR is used mostly for social interactions and thus also explicitly has a social benefit for the users, i.e., it satisfies their social needs. In this respect, social VR seems to give access to social experiences that many users tend not to experience on other digital social platforms or even the real world. Also, for many users, social VR is a means for entertainment, i.e., it serves, for example, to pastime, explore user-generated content, or distract from everyday life, which for some users was limited by the COVID-19 measures in 2020. In addition to the social and entertainment benefits, social VR is also a resource for personal well-being, such as expressing oneself freely and features that allow individual users to practice social interactions and overcome fears. These self-related usage motives illustrate the personal value some users assign to their social VR activities. Functional benefits, such as language learning, seem to motivate social VR involvement, but in principle, they are less reflected in the form of specific learning or work activities. The answer to the "Why" behind social VR engagement can also be inferred from the UMI results. These allow the conclusion that most users are intrinsically motivated and that the use and the associated benefits are of high personal relevance. This also allows the conclusion that social VR engagement seems to be sustainable for our participants. Social VR seems to be less simply an alternative to other social applications but seems to have a real added value [7]. This seems to lie mainly in the increased immersion and expressiveness due to technological aspects that, in consequence, creates a superior social experience, as the identified benefits emphasize. However, even if the better social experience, the social benefits, and the predominantly social activities show that social VR seems to be a very social platform due to its immersive nature and increased expressiveness, these aspects also seem to be accompanied by growing demands for improvement of those aspects. For example, users desire more affordable and comprehensive tracking technologies, increased sensory immersion, and improvements in terms of concrete social features. Nevertheless, also fundamental aspects of the user experience seem to require improvement.

Our results are relevant for related work in several aspects. First of all, we can say that the aspects identified in previous interview studies with small samples are also reflected in our results that are based on a big sample. In summary, our results confirm that social VR seems to extend the social and experiential qualities of traditional shared virtual spaces due to its technological characteristics (i.a., benefits regarding immersion and social experience, perceived social closeness). Additionally, they provide further evidence that social VR seems to support general and intimate socializing [43], self-expression and identity exploration [11], self-improvement and mental health, and learning skills and cultures [22]. Thus, the activities, motives, and benefits we identified are related to the groups of meaningful activities identified only recently during the writing of this paper [22]. For example, the activities for mental self-improvement (e.g., improving social skills) [22] are tightly connected to the *Self* category we present here. The previously formulated design recommendations (improvement of social connectivity, integration of communication affordances in and out of VR, increasing realism and naturalness [22]) were also addressed by our participants.

Our second contribution is a general and comprehensive view on the user-perspective on social VR. Although our results may offer a lower level of detail on specific topics identified in this paper than the results of in-depth interview studies [22, 26, 43], they allow an assessment of the relative importance of individual aspects, since we present the identified topics in terms of their frequency. Thus, our work provides a complementary perspective that offers a general overview of the topics previous papers dealt with in detail. We would also like to emphasize that our results are based on the everyday experiences of VR users who tend to be experienced with the medium of social VR and VR technology. Therefore, they form a valuable complement to findings from laboratory studies, which still make up the bulk of research methods, as VR technology is not yet a widely established medium in private end-user contexts.

Our third contribution lies in adding the users' perspectives to the literature concerned with current social VR applications' design practices. Our participant's desire for improved tracking technology (e.g., eyes, face) are in line with recently identified challenges and opportunities for the design of non-verbal communication in social VR based on a comprehensive overview of current social VR applications [41]. As we indicated, the tracking capabilities seem to be tightly related to the superior social experience. Thus our results emphasize previous conclusions that the development of software strategies and tracking technologies that improve nonverbal communication in social VR is a valuable research area. In addition, our results contribute to related work by supporting previous conclusions and indicate that it is worthwhile to bring users, developers, and researchers more in touch with each other. For example, while a previously crafted taxonomy of social VR application design areas also defines a "Self" category, this category is more related to specific features of avatars in social VR (i.a., "appearance customization", "controller tracking", "teleport") [17]. Thus, this other "Self" category does not necessarily reflect the self-related benefits we identified in our survey; however, it is linked to individual aspects of it (e.g., avatar appearance for self-expression). However, some self-related benefits we identified are linked to other categories of this taxonomy (e.g., overcoming social anxiety is linked to "interaction with others"). Regarding the unused potential of individual aspects of social VR, we would like to point out that learning and working were not very well represented in our sample. However, aspects such as learning sign language or doing light work do moti-

vate social VR engagement in individual cases. Especially against the background of the COVID-19 pandemic in the year 2020, this is a potentially rewarding application area for social VR, which is not yet represented in the taxonomy mentioned above. Therefore, we recommend integrating user-relevant motives into future design taxonomies to get a holistic perspective on the design of social VR features and tailor the design and research of specific features even more towards the potential user outcomes in everyday life.

6 Limitations & Future Work

Our results have to be interpreted with the following limitations in mind. We asked the participants to refer to the social VR application they use most often in their answers. Nevertheless, we used the data to draw a comprehensive picture and did not perform a platform-specific analysis. In this respect, we emphasize that most participants indicated *VRChat* as their favorite platform, which makes our results particularly representative for this user group. A rough examination has shown that individual categories show slight differences in the frequency of their mentions depending on the platform, which would have to be confirmed by a balanced sample. Therefore, it makes sense to generate such a platform-specific balanced sample in follow-up surveys or to explicitly refer to only one platform or several that are similar in features. Further, as illustrated in the sample description, our recruitment procedure gave us access to a not very diverse user group in terms of age, gender, region of residence, and thus probably cultural background. Consequently, it may tend rather to represent the user demographics of *Reddit* and its respective subreddits, and less of social VR. In particular, while our sample may represent users from America and Europe, it does not allow us to make generalizing conclusions about users from Oceania, Asia, or Africa. Future studies that directly reach out to social VR users should use recruitment procedures that provide access to a demographically diverse sample or try to specifically access users that we could not include in our survey. Besides, we have not yet conducted any analyses regarding the influence of individual characteristics such as personality or age. This must also be taken into account when interpreting our results. Therefore, we cannot assume that the categories and their relative importance derived by us apply equally to each user group. In summary, our results only allow us to make conclusions about social VR as a genre and users from different demographic groups, according to these limitations.

Methodologically, one limitation, in particular, should be mentioned. We decided to ask open questions and, in the sense of the UGT framework, we gave the participants the ability to reflect on their usage behavior. However, the variety of detail in the answers we received shows that not every participant wants to or can articulate themselves equally profoundly in such a kind of study. This is also shown by the high dropout rate, which led to the fact that we used different numbers of partial data sets for the individual analyses. Among these, there were detailed as well as concise and superficial answers. Of course, this is a direct disadvantage compared to in-depth interviews of individual users, but related to our study's goal, it is a limitation to be accepted. For follow-up studies in the topic areas we identified, we propose using predefined items and question domains but applying them so that participants can respond as unbiased as possible.

Besides the implications of the limitations above, we think it would be worthwhile to apply our methodological approach to less broad questions in social VR, such as the topics covered in the previous interview studies. Thus, prior knowledge on particular topics based on few users could be confirmed or extended by more extensive data sets. In doing so, however, we would fall back on the application of already predefined questions and assume this would lead to less fragmented datasets.

7 Conclusion

We investigated the "What" and "Why" of social VR usage and found, in line with previous work, that social VR extends the social and experiential qualities of traditional shared virtual spaces for a majority of users. Besides socializing with others, or the fun of playing in such virtual social worlds, users have also given us very personal information about the personal value they assign to social VR. So some find access to foreign cultures or best friends who live far away whereas others find access to social life in the first place by using such applications. As already noted by other researchers in this field, a thorough look at what users value about social VR eventually helps identify research and development opportunities by indicating what features of social VR are currently crucial for users but may be improved in the future. We identified a desire for better and affordable tracking technology, increased sensory immersion, and further improvement concerning social features. Our results indicate that, in everyday life, as well as times of limited opportunities for real-world social interaction (as in the ongoing COVID-19 pandemic), social VR's promise is the access to authentic and meaningful social interactions over distance for people who are physically separated from each other.

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A.3. Something Personal from the Metaverse: Goals, Topics, and Contextual Factors of Self-Disclosure in Commercial Social VR

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Something Personal from the Metaverse: Goals, Topics, and Contextual Factors of Self-Disclosure in Commercial Social VR

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ABSTRACT

Current Social VR literature provides limited insight on one of the most critical behaviors for developing and maintaining interpersonal relationships: self-disclosure. Therefore, we present an online survey (N = 126) investigating how users disclose personal information to each other in Social VR. Our results indicate that many participants see in Social VR access to authentic connections with others despite tending towards skepticism and privacy concerns. Most users disclose sexuality-related information, lifestyle preferences, and personal goals. In contrast, information that breaks anonymity, such as real names and more intimate aspects of oneself, are shared less commonly. Thereby, self-disclosure decisions depend on factors like the relationship to or age of disclosure recipients, the privacy of a virtual environment, the group size, or the activity context, and is driven by different goals, i.a., relational development or exploration of oneself. These insights advance the understanding of current Social VR users and their behavior by directing future research on self-disclosure-based relationship building in Social VR and outlying broader design implications for the future metaverse.

CCS CONCEPTS

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

KEYWORDS

self-disclosure, social virtual reality, online social interaction

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1 INTRODUCTION

Disclosing personal information to others is one of the most important factors influencing the formation and maintenance of interpersonal relationships. It thus forms the basis for healthy social ties to acquaintances, friends, and significant others [2, 39, 74]. Modern computer-mediated communication technologies contribute to interpersonal communication and relationships in large parts of private and public life (e.g., [18, 26, 30, 59, 91]) and impact how we reveal personal information to others [9, 51]. The study of self-disclosure (i.e., sharing personal information with others) in computer-mediated social contexts has become established in HCI research. In particular, it focuses on how individual self-disclosure is affected by technological affordances of a specific medium designed for social communication like social networking sites (e.g., [72, 90]) and virtual social worlds (e.g., [34, 69]).

A novel venue for mediated social experiences is Social VR, an emerging ecology of commercial applications for avatar-based remote social interaction in shared virtual environments using VR technology (i.e., head-mounted displays) [53, 54, 65]. Social VR offers embodied and immersive social experiences comparable to face-to-face interaction due to its verbal and non-verbal expression capabilities [49, 79], and the variety of social activity contexts it offers [44, 49, 53, 54, 58, 76, 89].

Alongside the access to a new communication venue like Social VR naturally comes the question of how its technological qualities affect aspects of social interaction like self-disclosure. Though, HCI research only recently began to study self-disclosure in Social VR. Insights so far based on user interviews demonstrate trade-offs between enjoying natural ways of self-disclosure and being concerned about privacy risks [50]. However, users reported feeling comfortable disclosing both emotional, and personal information [50]. Although previous findings provide interesting insights into individual attitudes and behaviors of a few Social VR users, they do not allow the identification of general patterns of attitudes and behaviors related to self-disclosure in Social VR. For example, current findings do not provide insights into quantified tendencies to disclose or not disclose certain topics or how different context factors may generally influence the disclosure of certain information types. With our study, we wanted to identify such general patterns of opinion and behavior by answering the following research questions:

RQ1 What do users think about disclosing to others in Social VR?

RQ2 What topics do they disclose?
RQ3 What goals drive their self-disclosure?
RQ4 What contextual factors influence their disclosure?
RQ5 What technical channels do they use to disclose?

In contrast to previous interview approaches, we conducted an online survey to obtain data from a potentially larger number of Social VR users. By choosing this approach, we eventually contribute to the still-emerging domain of Social VR research by increasing the representative value of our results. Approaches like ours and previous works that reach out to current Social VR users directly provide insights into the actual day-to-day usage patterns and experiences. These insights enable us to grasp the potential significance of Social VR for satisfying basic social needs today and in the future induced by social interactions like self-disclosure. Further, understanding users' rules dictating their disclosure of personal data in Social VR is mandatory to inform the design of safe and healthy virtual spaces, given current public controversies on the general handling of user-generated data in virtual reality [24, 66]. Additionally, our work is timely as the COVID 19 pandemic has reshaped our world with its far-reaching social distancing measures, which significantly increased the need for alternatives to physical meetings and also revealed issues with existing technical solutions [5]. Furthermore, investigating these questions in particular in the context of Social VR contributes to the basic understanding of social interactions in virtual environments that may become part of the future metaverse. The metaverse refers to a concept of a persistent digital world that converges technologies like AR and VR with physical reality and succeeds the internet of today. The term goes back to the 1992 novel *Snow Crash* by Neal Stephenson [73], and is currently broadly discussed in public after the restructuring of *Facebook*, which now belongs to the parent company *Meta* [56, 81].

2 BACKGROUND

In this section, we briefly review the literature on the basics of self-disclosure and provide some examples of how computer-mediated communication introduces technical characteristics that influence how people engage in self-disclosure. As our goal is not to compare self-disclosure in Social VR directly to other forms of computer-mediated self-disclosure, we do not provide a broader and nuanced review of literature in this area. Subsequently, we summarize the current Social VR literature landscape, emphasizing the role of Social VR for interpersonal relationships so far and in the future. Lastly, we discuss the few existing insights on self-disclosure in Social VR and explain our work's contribution to this limited research domain.

2.1 Self-disclosure

Self-disclosure is the verbal or non-verbal revealing of personal information to others [20, 29, 38, 61, 84]. The revealing of personal thoughts, experiences, and feelings stimulates basic needs for social connectedness and involves neural and cognitive activities associated with feelings of reward and thus is intrinsically rewarding [78]. Derlega and Grzelak (1979) described five main motivations of self-disclosure in their functional theory (as cited in [61]): social validation, relief of distress, relational development, identity clarification, and social control. Depending on situational cues and individual attributes, one or several of these motives eventually motivate people towards self-disclosure as a means to achieve social rewards. Thereby, the process of disclosing personal information is always a balancing of the possible rewards and the risks posed by the potential vulnerability of revealing sensitive personal information to others [2, 20]. As a strategy to maximize beneficial disclosure outcomes and minimize its risks, establishing a dyadic boundary surrounding oneself and trusted recipients within a safe environment functions as a privacy control mechanism. Within such a boundary, intimate disclosures are most likely to happen in conversations with close friends or with strangers [20].

Literature categorizes types of self-disclosure behavior along various dimensions such as the depth or intimacy of information, breadth or thematic diversity of information, the duration, frequency, authenticity, or the willingness to disclose [2, 12, 38, 64]. Further, self-disclosure literature provides many findings and ongoing discussions on various factors that influence self-disclosure. However, as a detailed review would be out of this paper's scope, we instead refer to a literature overview by Ignatius and Kokkonen [35] that define three broad categories of potential influencing factors: characteristics of the disclosing like their motivation and mood, characteristics of the recipients like the relationship to them, their age, perceived status, or number of recipients, and situational factors like the environment's aesthetics, interpersonal touch, cultural context, or the used communication channel.

Self-disclosure is inherently integrated with the development of social relationships according to the Social Penetration Theory [2, 14]. This theory explains how social relationships deepen over time and move from casual, superficial encounters to intimate and meaningful, long-lasting relationships. Thereby, self-disclosure functions as a fundamental driver for relationship development, as with the reciprocal act of disclosing personal information, people get to know each other better [2, 14]. Accordingly, disclosing personal information and the type of disclosed information determines how fast and in what direction a relationship develops. The onion model is a popular metaphor that describes the interrelationship between self-disclosing different types of information and interpersonal bonding [14]: just as an onion can be taken apart layer by layer until its core, more and more personal and intimate information about each other is revealed along the development of a relationship. Thereby, outer layers can be associated with superficial, less intimate information typically disclosed early in relationships, such as likes and dislikes in clothing and music. Middle layers reflect more intimate topics, like political views, personal goals, spiritual values, or deep fears, typically disclosed later in relationships. The innermost layer, i.e. the core, represents the most intimate information related to one's concept of self or core personality. People share this information usually with significant others, close friends, or close family members that represent the final stages of relationship development (Taylor & Altman, 1987 as cited in [14]).

2.2 Computer-mediated Self-disclosure

Today, communication technologies play an essential role in interpersonal communication and thus are also an established instrument of self-disclosure. Although the scientific discourse does not readily permit general statements about the differences between

face-to-face and computer-mediated self-disclosure, there is consensus that specific technology-induced key characteristics moderate online self-disclosure [60, 71]. This section only provides a brief overlook over selected affordances of modern computer-mediated communication that are typically discussed in self-disclosure literature.

A crucial characteristic is the varying degree of anonymity that some systems provide over different communication channels (e.g., social network sites, forums). Thereby, an increase of anonymity may promote disclosure of intimate information as a result of the perception of increased comfort, and lower accountability [7, 15, 36, 75]. Also, the absence of social cues, like non-verbal communication signals, or low degrees of perceived social presence (e.g., in text-based vs. avatar-based interaction) are assumed to promote self-disclosure on different dimensions as it reduces the perceived uncertainty caused by the missing of social cues [6, 71, 82]. Another critical feature often provided by media that allow asynchronous communication is the editability of messages before and after the actual disclosure. Editability enables a conscious and strategic selection, as well as the composition of different self-disclosing media content, which can paint a particularly filtered self-image [22, 83]. Further, platforms like *Facebook* integrate communication channels that allow users to engage in dyadic contexts similar to face-to-face situations (e.g., through private messages) or in large-audience contexts that have no face-to-face equivalent (e.g., broadcasts to an anonymous public through status updates). Users choose different channels for self-disclosure depending on the anticipated social rewards: e.g., social validation is mainly achieved by public status updates, whereas private messages instead account for relation development [9]. More generally, ubiquitous access via mobile communication devices allows for a constant low-threshold opportunity to reveal oneself to others and to be aware of others' disclosures [51]. However, while online self-disclosure induces positive feedback loops with beneficial psychological outcomes [3, 43], the characteristics above can also have significant negative consequences arising from tendencies to compulsive self-disclosure behavior [21].

Unlike the aforementioned types of sociotechnical systems that typically involve self-disclosure via text-based communication, other systems like online games often utilize avatar-based interaction within a synchronous communication context, introducing other types of affordances. In particular, animated, anthropomorphic avatars add a layer of natural non-verbal communication cues, like gestures, postures, or mimics, depending on the fidelity and mode of control of the system at hand. Further, avatars can often be individualized in terms of visual traits, allowing users to create a virtual representation of themselves that may identically reflect their physical appearance or consciously differ from it. Accordingly, scholarship demonstrates avatars' longstanding ability to satisfy the need for expressing and presenting one's self online [16, 19, 31, 41, 63]. However, avatars affect not only the types of communication channels that are available for self-disclosures but can also affect self-disclosure itself in subtle or unconscious ways. For example, perceived avatar-self similarity in terms of appearance and psychological and behavioral attributes may promote or inhibit self-disclosure as a function of induced feelings of either self-presence or identifiability within a virtual environment [34]. Further, based on the popular *Proteus Effect* self-avatar perceived attributes, like one's avatar's attractiveness, can affect one's self-disclosure behavior: e.g., controlling a more attractive avatar leads to more intimate self-disclosures compared to controlling a less attractive avatar [87]. Furthermore, avatars are not only relevant for how we disclose but also for how we perceive others' self-disclosure. Accordingly, a study comparing the perception of video-based and avatar-based self-disclosure found that an avatar-based disclosure can be perceived as authentic as a video-based disclosure of an actual human and also induce comparable levels of empathy [69].

After we have exemplified in this short overview that technological affordances can impact self-disclosure, in the next section, we introduce Social VR, a popularity-gaining genre of applications based on avatar-mediated interaction.

2.3 Commercial Social VR

Social VR refers to a genre of commercial multi-user VR applications that enable remote users to interact with each other in shared virtual environments through VR technology (e.g., immersive head-mounted displays). Within these virtual social worlds, users are commonly represented by avatars which they control with their body movement due to tracking technology [53, 54, 65]. Since 2015, Social VR applications have grown in popularity and today are, in fact, predominantly used to socialize with others [76]. Popular platforms include *Altspace VR, VRChat, Horizon Worlds*, and *RecRoom*. These platforms are owned by companies like *Microsoft, HTC*, and *Meta* (formerly *Facebook*), which indicates the commitment of large technology companies towards potentially reshaping the future of mediated interpersonal communication. Despite fundamental similarities, a brief look at these applications shows that they can roughly be distinguished based on the specifics surrounding their implemented avatar systems and the number and types of different activities users can engage in. Early Social VR literature provides a high-level analysis of different platforms' avatar-systems [40]. It illustrates how different applications provide varying capabilities related to, i.a., in-world avatar customization, avatar import features, the use of humanoid or other avatar styles, or the support of communication features like automated facial expressions [40]. Activity-wise, recent literature illustrates that Social VR users engage in diverse social and entertainment activities provided by such platforms [8, 44, 76]: having conversations, hangouts or intimate meetings with strangers or known others in private or public spaces, playing integrated or community-made games, creating and exploring different worlds, watching video content, listening to music, gathering for social events like parties [8, 76]. Interestingly, users not only show usage patterns that are directly attributable to the available platform features (e.g., world creation with creation tools). They also describe use cases that were probably not intended by the platforms' creators, such as sleeping in *VR Chat* within user-created so-called sleep worlds [44].

Social VR applications are rooted in the domain of collaborative virtual environments [11], and, although it is still an emerging consumer application genre, the current literature on this specific subject is already diverse. It includes literature that aims to systematize the landscape of commercial Social VR design practices (e.g., [37, 40, 53, 79]), as well as an increasing body of work that focuses

on specific aspects of user behaviors and experiences for example, in the context of harassment [13], different user groups [1, 45, 46], general user motivations [44, 76], usability issues [42], relationship building during COVID 19 global pandemic [48], and psychological benefits induced by platform engagement [8].

In sum, previous research indicates that Social VR offers a variety of social experiences comparable to face-to-face interactions in terms of verbal and non-verbal expression capabilities in group or intimate contexts [44, 49, 49, 53, 54, 58, 89]. In particular, Social VR affords rich non-verbal interactivity which mimics that of the offline world, including gazes, nods, and other forms of naturalistic behavior [49]. Moreover, recent work found initial empirical evidence for associations between facets of Social VR engagement and psychological benefits like feelings of relatedness, self-expansion, and enjoyment [8]. Thus, Social VR's promise is the access to authentic and meaningful social interactions over distance [8, 25, 44, 48, 76, 89]. This promise is relevant not only in times of limited opportunities for real-world social interaction but also in cases where individual people may not be capable of engaging in face-to-face social interaction. That it has potential to fulfill this promise has been demonstrated in previous work on its capabilities to support meaningful relationships [25, 48, 89, 89] and interactive social experiences [44, 48]. It also satisfies social needs [76] and has beneficial psychological outcomes [8]. Moreover, recent trends in research indicate that Social VR can even introduce novel social experiences in the future as it provides fundamentally different approaches to mediate social interaction experiences. For example, by augmenting familiar social cues with virtual social artifacts (e.g., adding visual effects to virtual high-fives) [52, 68, 77]. Concluding, as self-disclosure is an essential part of social interaction and relationship building, by studying it in the context of Social VR, we aim to advance the understanding of how users create meaningful social interaction and bonds in Social VR.

2.4 Self-disclosure in Social VR

Social VR shares similarities with other online non-VR platforms we described in section 2.2 in the way people can communicate with each other. For example, users in Social VR can remain anonymous, can have representations of varying realism and style, can communicate with each other asynchronously via text messages, and can disclose to only few individuals or larger groups of users in private as well as public contexts. Though, as Social VR is primarily designed for synchronous social interaction via VR technology, other aspects from social network sites or forums, like the editability of messages and ubiquitous access to the platforms may be less prevalent. Further, Social VR platforms offer a variety of social activities based on real-time interactions, that may introduce novel social contexts for self-disclosure, that are not realizable on other platforms.

However, the most outstanding difference between Social VR and other venues of computer-mediated social interaction like social network sites and non-immersive virtual environments, is that users interact with each other while being immersed in a virtual environment that they perceive from a first-person perspective, and where they embody and control an avatar. As such, Social VR presents a naturalistic opportunity for self-disclosure which nearly mimics that of the offline world. Current applications already enable diverse channels of specific non-verbal communication cues [79] and the simulation of intimate interactions like virtual body contact (e.g., hugs, holding hands, and dancing), which may lead to new forms of computer-mediated self-disclosure that resemble experiences from face-to-face interaction but are not supported by other technologies. Further, more recent work indicates that avatar-based communication in VR could combine beneficial impacts of anonymity of online communication with experiential qualities of face-to-face interaction [4, 67, 69].

While avatar-based communication in Social VR introduces its own technological affordances that may impact relationship building through self-disclosure, only one study, to the best of our knowledge, has investigated modes of self-disclosure in commercial Social VR so far [50]. This work conducted 30 in-depth user interviews focusing on the type of information shared and to whom users disclose while emphasizing users' privacy concerns introduced by the applications' technological affordances. The findings demonstrated that users feel comfortable disclosing both personal and emotional information and detailed that Social VR requires trade-offs relating to revealing information to better use the system. These trade-offs also reflect, that Social VR provides new ways of wanted or unwanted self-disclosure by implicitly embedding disclosure of gender-related information or body capabilities in the system by using voice chat and body tracking. Thereby, people differed in their decision to disclose only to others they are already familiar with, or only to anonymous others they do not know. Relating to the factors contributing self-disclosure [35], these findings provide initial evidence, that in Social VR characteristics of the recipient (relationship with him or her), and situational factors (different communication channels) affect self-disclosure decisions. Though, there are further potential recipient and situational characteristics that may impact self-disclosure and relate to Social VR features recently investigated or highlighted in literature: access to public and private spaces [37, 54], interaction between young and old [45, 46], access to diverse activities and varying group sizes [8, 44, 76, 89]. Further, the motives behind self-disclosure in Social VR, as well as insights into what communicative affordances users utilize for disclosing themselves has not yet been addressed. Furthermore, previous findings are based on a relatively small number of users due to the applied methodology. These gaps and limitations motivate our own research questions and choice of method to naturally extend current insights and provide a broader perspective on self-disclosure in Social VR.

3 METHOD

As opposed to previous work that applied extensive interviews with only a few Social VR users [50], we decided to collect data from a larger number of users by conducting an online survey. This would allow us to increase our results' representative value and identify potential patterns of opinion and behavior related to self-disclosure shared by many users. Further, by mainly applying closed-ended questions with answer categories derived from the literature (e.g., self-disclosure goals, Social VR activities) instead of open-ended questions, we potentially increase the survey's response rate by

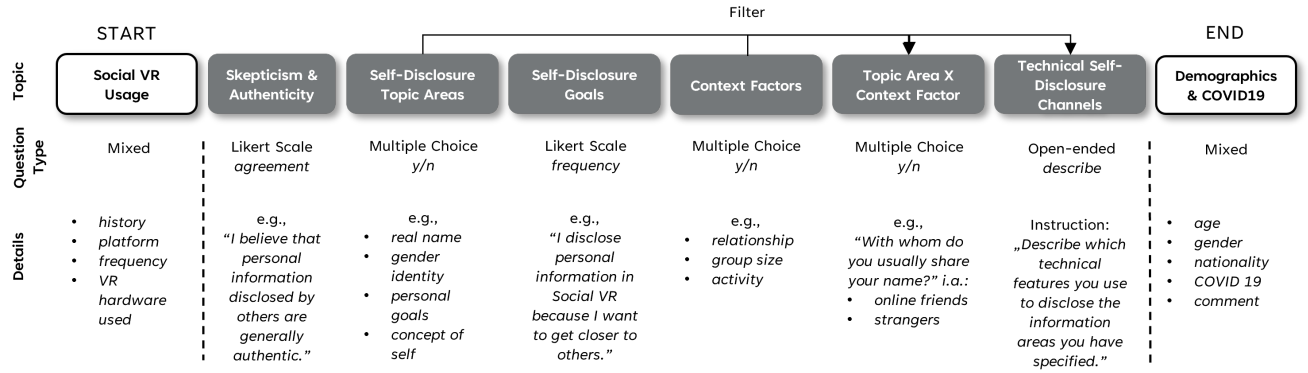

Figure 1: Survey structure with information on question types and example items for each of the survey topics.

increasing the convenience of answering the questions. In the following, we will explicate the survey design and the procedure of data collection.

3.1 Survey Design

The survey structure is illustrated in Figure 1 and is roughly composed of three major parts: Social VR usage data, self-disclosure, and demographic information.

3.1.1 Social VR Usage, Demographics & Confounding Variables. To characterize the sample adequately in terms of Social VR expertise, we asked participants to indicate when they started using Social VR, how they would characterize their usage intensity, favorite platform, and mode they use (VR vs. Desktop). They were further instructed to refer their survey responses to their favorite Social VR platform. As demographics, we assessed gender identity, age, nationality, and (as an open-ended question) identity aspects that participants thought of being relevant to the subject of interest. Further, we asked participants if their Social VR engagement started or intensified in the course of the COVID 19 pandemic and if self-disclosure in Social VR now plays a more critical role for them due to the pandemic. We included the last part to estimate any confounding effects induced by personal challenges during the pandemic situation at the time of the survey [17].

3.1.2 Skepticism & Authenticity. To assess the general opinion on self-disclosure, we asked participants to indicate their general skepticism towards self-disclosure, if they had any privacy concerns, and if they think their own and others' self-disclosure in Social VR is authentic.

3.1.3 Self-disclosure Topic Areas. We crafted a catalog of three different topic areas, including relationship-building topics, identifiers, and sexuality. In sum, participants were asked to indicate along 12 individual items whether they do or would disclose a specific information type. Topics associated with relationship-building were defined based on assumptions of the Social Penetration Theory [2, 14] and represent the types of information that humans typically disclose to others in the course of social relationship development. The topics range from information that we would disclose rather to someone we have met only recently to information we would only disclose in an intimate, long-lasting relationship. Accordingly, we assumed that participants would implicitly associate the different topics with different degrees of intimacy. They were asked to indicate if they disclose or would disclose information from the following topic areas, ranging from lower to higher degrees of intimacy: lifestyle preferences, goals and aspirations, religious and political convictions, fears and fantasies, their concept of self. The topic area identifiers included external contact information, residence information, physical appearance, and real name. Recent research on LGBTQ+ communities in Social VR [1] motivated the inclusion of the sexuality category, which contains the information types biological sex, gender identity, and sexual orientation. Identifier and sexuality information reflect aspects of one's identity and anonymity directly related to technological affordances of avatar-based interaction in Social VR (e.g., use of custom user names and avatars and voice chat).

3.1.4 Self-disclosure Goals. To assess what social rewards drive self-disclosure in Social VR, we created five items based on the functional approach to self-disclosure [61] that assess how often each of the following goals drives self-disclosure in Social VR: self-expression, relationship development, social validation, social control, identity clarification.

3.1.5 Context Factors. We chose to include several Social VR features recently investigated or highlighted in Social VR literature as potential influencing factors on self-disclosure. Each of these factors represents social contexts in which social encounters in Social VR typically happen. Further, these factors relate to general influencing factors of self-disclosure in other contexts based on the literature review. As socializing is one of the key motivations for Social VR engagement [76] and relationship to others affects self-disclosure in face-to-face interaction [2, 14, 35] we included the relationship to others as one contextual factor.

As Social VR applications typically grant access to either public or access-controlled private spaces [37, 54], we included the privacy of a virtual space as another contextual factor. This feature relates to the privacy control mechanism of establishing dyadic boundaries as safe spaces for self-disclosure [20].

We considered the conversation partner's age as a relevant context factor, as Social VR practically does not restrict usage to specific age groups, and previous work found that adult-minor interaction underlies complicated dynamics in Social VR [45, 46]. Age is also a potential impact factor of self-disclosure [35].

Due to the diversity of activities offered in Social VR [76], social encounters can happen in a dyadic, small group, or large group contexts, which can impact self-disclosure in face-to-face contexts [35]. Thus, we also included the context factor group size and the activity type in the survey.

For each f the factors, participants were asked to indicate if it affects their decision to self-disclose in their favorite Social VR application. Additionally, they could indicate other contextual factors that were not reflected in our pre-selection.

3.1.6 Topic Area X Context Factor. For each context factor, we further derived specific social contexts that would allow us to understand how each factor may influence self-disclosure. Participants were asked to indicate if they would disclose certain information in a specific context filtered by the possible combinations of the topic areas and context factors they indicated earlier in the survey. For example, if participants indicated to disclose information related to their self-concept and that the privacy of a virtual space affects their disclosure decision in general, they had to indicate if they disclose information related to their concept of self in the following contexts: private spaces, public spaces.

3.1.7 Technical Self-disclosure Channels. As Social VR provides several channels for self-disclosure that may be used voluntarily or forced [50] and extend disclosure opportunities usually provided in other social online worlds (e.g., natural gesture-based communication) or face-to-face conversation (e.g., emotes), we asked participants to think about the technical channels they use to disclose the information they indicated earlier in the survey. As opposed to the previous survey sections, we decided to apply open-ended questions in this section, as previous work explicates that users may use certain platform features in ways other than those intended by developers or researchers (e.g., sleeping in VR [44]). By asking open-ended questions, we prevent participants from being influenced by only asking them about channels we expect them to use and preserve the opportunity to identify novel ways of self-disclosure that users may have devised in Social VR.

3.2 Data Collection

We advertised this survey in several channels related to Social VR, VR, and sample recruiting via posts on *Reddit*, *Discord*, *Facebook*, and a *WhatsApp* group we got invited into by Social VR users. Participants were required to be at least 18 years old and be actively engaged in a Social VR app (e.g., Recroom, VR Chat, Neos VR) at the time of the survey. We asked admins for permission before posting survey links in each community. After the first two weeks, we have made a re-post, accompanied by already collected statistics on general sample information (e.g., survey completion rate, Social VR usage statistics, and the favorite platforms so far) to maintain community attention. Eventually, we did a second re-post after two months in the *AltspaceVR, Bigscreen, Neos VR, RecRoom*, and *VRChat* community to achieve a more balanced data set in terms of Social VR platforms. Data collection lasted from mid-May to the end of July 2021.

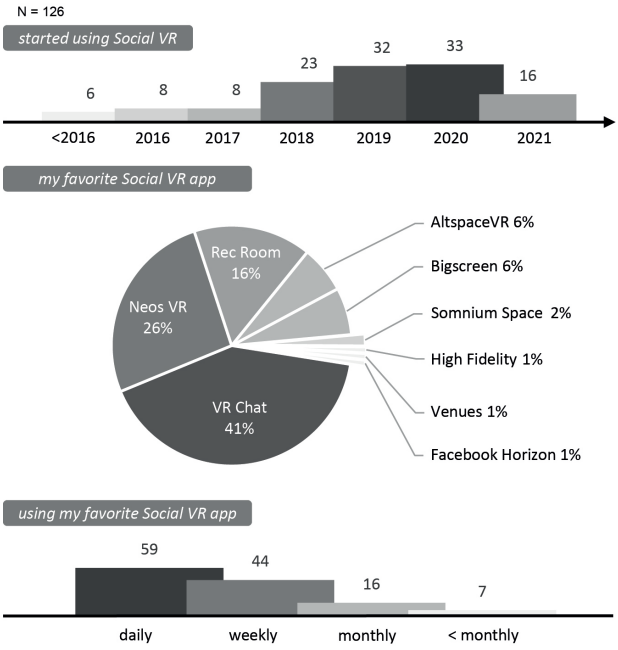

Figure 2: Social VR usage habits of the sample.

We hosted the survey on a custom installation of the survey application *Lime Survey*. There was no compensation for participation. The first author's faculty's ethics committee approved the survey and we followed the ethical considerations for Social VR research outlined in Social VR Literature [47].

3.2.1 Data Exclusion Criteria. Participants were excluded from the analysis if their responses met one of the following criteria: empty data set, indicated being under 18 years old, using Social VR mainly in desktop and not VR mode, indicated a VR app that we do not refer to as Social VR (e.g., Beat Saber), left survey before technical self-disclosure channels part, too short processing time measured against average survey time, presence of obvious non-serious answers in open-ended questions.

4 RESULTS

From 221 survey responses, we obtained 126 complete and 95 incomplete responses. To increase the data for analysis, we also decided to include incomplete datasets that only missed demographic data, as we did not aim to search for associations between these and other data in this initial investigation of the topic. After checking all entries against exclusion criteria, we ended up with **126 valid responses**.

4.1 Demographics, Social VR Usage & COVID

Among the 126 valid entries, 107 participants indicated their gender identity: 77 cis male, 14 cis female, 11 non-binary, five transgender female. Five participants indicated to be unsure about their gender

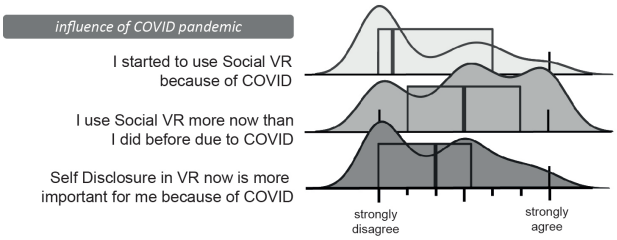

Figure 3: Combined density and box plots illustrating answer distribution regarding the impact of the COVID 19 pandemic on Social VR usage habits.

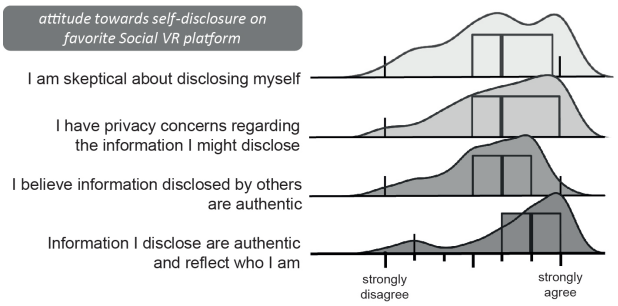

Figure 4: Combined density and box plots illustrating answer distribution regarding the general attitude towards self-disclosure in favorite Social VR application.

identity or gender-questioning. Age ranged from 18 to 60 years (n=107) with an average age of 28.35 years (*Mdn* = 26). Most participants lived in North America at the time of the survey, with 62 from the United States of America and nine from Canada. One participant each lived in Mexico and Brazil. Thirty-two participants lived in Europe, with most of them in the UK (8), Germany (6), Poland (4), Sweden (3), Netherlands (2), Denmark (2), and one participant each in eight other European countries. Six participants lived in Australia.

Figure 2 illustrates the sample characteristics in terms of Social VR usage habits. 64.3% started using Social VR in 2019 or later. 83% indicated either *VR Chat*, *Neos VR*, or *Rec Room* as their favorite Social VR app. Six other applications were each indicated by less than ten people. 46.8% indicated to use their favorite Social VR app daily and 34.9% weekly.

The COVID 19 pandemic seems to have affected the Social VR usage habits of some participants (see Figure 3). 58.9% slightly or strongly disagreed with having started Social VR because of the pandemic (*Mdn* = 1.5). 46,4% slightly or strongly agreed that the pandemic increased their Social VR engagement (*Mdn* = 4). 25% agreed that self-disclosure in Social VR got more important for them because of the pandemic (*Mdn* = 3). However, response ranges of all three questions cover the entire scale and indicate inter-individual differences among participants.

4.2 General Opinion

Overall, the general attitude towards self-disclosure in Social VR was ambivalent as many participants tended to agree with negative as well as positive statements (see Figure 4). 60.3% of participants at least slightly agreed to be skeptical (*Mdn* = 5) and 64.8% slightly or strongly agreed to have privacy concerns (*Mdn* = 5) regarding disclosure of personal information on their favorite Social VR platform. 57.1% slightly or strongly agreed with perceiving others' information disclosed to them being authentic (*Mdn* = 5) and 79.4% slightly or strongly agreed disclosing authentically to others (*Mdn* = 6). However, the response ranges of all questions cover the entire scale and indicate inter-individual differences among participants.

4.3 Topics of Self-disclosure

Overall, participants indicated to disclose all of the queried information categories. However, the topic areas partly differ significantly in the number of participants who disclose.

On average, identifiers like external contact information, one's physical appearance, and one's real name, are the topic areas that least participants are disclosing on their favorite Social VR platform (around 35%)(Figure 5). However, over half of participants would share residence-related information (e.g., country or area of residence).

Sexuality-related information tends to be disclosed from most participants on average (<73%).

Information pertaining to relationship building is revealed by varying numbers of participants. Most participants disclose lifestyle preferences (92.06%), and personal goals and aspirations (74.60%). Less than half of participants disclose religious and political convictions, and fears and fantasies (each 38.89%). However, roughly half of participants disclose or would disclose information related to their concept of self.

4.4 Goals of Self-disclosure

Self-disclosure seems to be variably motivated by different goals (Figure 6), though all goals included in the survey seem to drive self-disclosure to at least some extent.

Overall, getting closer to others (*Mdn* = 5), and getting oneself and others to understand oneself (*Mdn* = 5) seem to be most often the motivation behind self-disclosure for most participants. However, the other goals are also at least sometimes relevant for 50% of the participants (each with *Mdn* = 4). Comparing the distribution patterns of responses for each goal, relieving distress, and influencing others' self-disclosure behavior have the most responses below sometimes and thus a subtle tendency towards being less relevant than the other goals. Further, distribution information indicates partly significant inter-individual differences, as response ranges cover the entire scale for all goals.

4.5 Importance of Context Factors

Figure 7 illustrates the general importance of the context factors relationship, privacy, age, group size, and activity based on relative

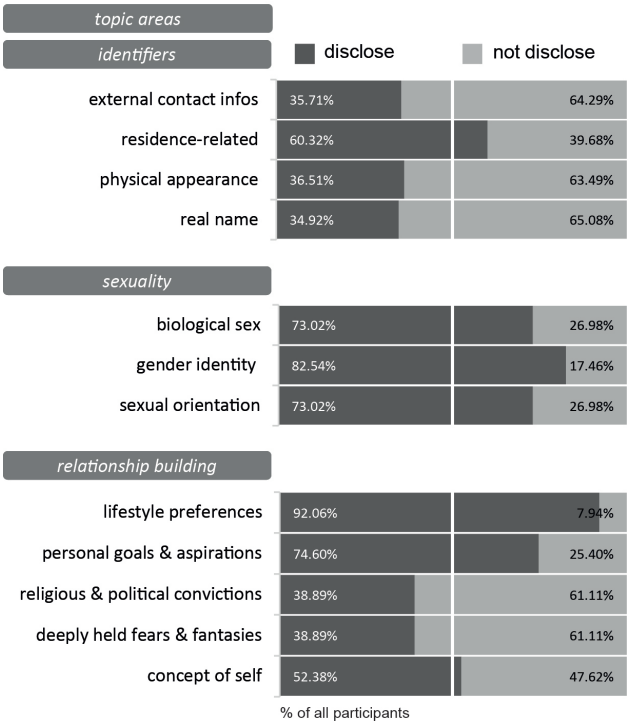

Figure 5: Relative frequencies for how many participants reveal different information on their favorite Social VR platform.

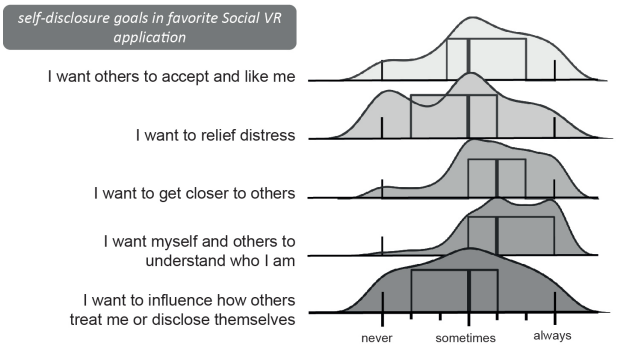

Figure 6: Combined density and box plots illustrating answer distribution regarding how often self-disclosure goals motivate self-disclosure on favorite Social VR platform.

frequencies of participants' answers. The bar chart of Figure 7 illustrates the relative frequencies of how many participants indicated that a factor is important to them when deciding to disclose in general. In summary, each of the assessed factors is important for at least some participants, as each factor was indicated as such by over 50% of participants. Though, relationship to the communication partner seems to be most important, as it was indicated by most of the participants (91.27%), followed by the privacy of the virtual environment (73.02%), the conversation partner's age (65.08%), the group size (60.32%), and the activity in which communication takes place (57.94%).

16 participants indicated additional factors that influence their disclosure decision that we synthesized to the following seven categories: the general impression of the communication partner (4 mentions), contact opportunities on other digital communication platforms (3 mentions), influence from drugs like alcohol (3 mentions), perceived reciprocity (3 mentions), perceived geographical background of partner (2 mentions), the current conversation trend (1 mention), and the perceived platform security (1 mention).

Complementing the bar chart, a heatmap in Figure 7 illustrates the importance of each factor for disclosing the different types of information. It is crucial to note that the % values in the heatmap are relative to the individual subsets of participants that indicated they would disclose the cell row's topic (illustrated in Figure 5). We deliberately decided not to indicate frequencies relative to the whole sample, as this would not reflect the survey structure. As described in the Methods section, we designed the survey to ask respondents only about topic-factor combinations resulting from their respective individual statements about the topics they disclose and the factors that influence them. Thus, the cell values indicate the number of participants of aforementioned subsets, that indicated later in the survey to disclose the corresponding information only in some of the specific contexts associated with the context factors (e.g. people that disclose their real name only in private but not in public environments or vice versa). In general, the higher the value, or the darker the hue of a cell in the heatmap of Figure 7, the more people indicated with their response pattern that the respective context factor is important for their disclosure decision. In other words, the darker a cell's hue, the higher the probability that the disclosure of the type of information depends on the context factor, or, the more important the factor seems to be for the disclosure decision. Thus, the heatmap effectively identifies general patterns of the factors' relevance for individual topics. Based on this color-coding a brief look at the heatmap indicates, that relationship seems to be of particular importance for disclosing identifiers, personal goals and aspirations, fears and fantasies, and the concept of self. In contrast, age consistently appears to be somewhat less important for the disclosure of each topic. Regarding the other factors, no specific pattern occurs in the heatmap. Though, it can be summarized that based on values from 20% to around 50%, each context factor seems to influence the self-disclosure of individual topics to some degree.

4.6 Self-disclosure in Different Contexts

Figure 8 illustrates what kind of influence the contextual factors have on the disclosure of individual pieces of information and shows in which specific contexts of their favorite Social VR application participants disclose certain information. For this purpose, we present relative frequencies in a heatmap to reveal general patterns of the context factors' influence. As with the heatmap in Figure 7, the cell values do not refer to the total sample but to individual subsets of participants according to the information they disclose and factors that influence them. Though, Figure 8 uses a diverging color-coding

Figure 7: Relative frequencies of which factors impact self-disclosure decision in general (bar chart) and for specific topics (heatmap).

consisting of blue hues for high values, yellow hues for medium, and red hues for low values. Generally speaking, blue areas in the heatmap indicate contexts where many participants would disclose certain information, whereas red areas indicate contexts where many participants would not disclose certain information. Accordingly, yellow areas represent contexts where no obvious preference can be identified.

In summary, there are some clear patterns of self-disclosure behavior for each of the context factors in the sense that there are specific contexts in which disclosure is either more or less likely to happen than in other contexts. These patterns are illustrated in the heatmap by consistently colored columns, whereby there are both blue and red-colored columns within a context factor area. In the following, we briefly summarize the patterns of self-disclosure for each context factor.

4.6.1 Relationship. In terms of the type of relationship, the heatmap shows a clear tendency for self-disclosure to be more likely if the recipient was known better. More precisely, participants for whom the relationship is important to disclose a particular topic would probably disclose it to people they know better. This pattern is illustrated in the columns associated with friends (online and offline), which contain higher values than those associated with loose friends, which have higher values than the stranger column. Further, there seems to be a slight tendency for disclosing information pertaining to sexuality and relationship-building to people only known online rather than to people also known offline (e.g., sexual orientation, fears and fantasies).

4.6.2 Privacy. Most people willing to disclose a particular topic depending on the privacy of the virtual environment would do so in a private space with regulated access and rather not in a public space. Though, information regarding one's biological sex, gender identity, and lifestyle preferences are comparably likely to be disclosed in public or private virtual spaces without a clear tendency towards a positive or negative disclosure decision.

4.6.3 Age. Those participants that base their disclosure decision on the age of the conversation partner do so in clear patterns. Across all topic areas, self-disclosing to younger people is not preferred, whereas disclosure to same aged and older people is very likely, with a slight preference for same-aged people.

4.6.4 Group Size. A clear pattern of disclosure preferences is also revealed for the context factor group size: The bigger the group of potential recipients, the less likely it is that people disclose personal information. Thereby, the heatmap reveals a clear preference of dyadic or small group contexts over groups of more than 10 people where it is unlikely that people disclose personal information. This pattern is consistent across all information categories. However, external contact information seems to be only disclosed in dyadic contexts. Similarly, fears and fantasies, and the concept of self, also tend to be disclosed rather in dyadic contexts than in small groups.

4.6.5 Activity. Those who disclose certain topic areas depending on the activity context also do so in certain patterns: hangouts and intimate get-togethers are activities where participants would most likely disclose personal information. Although there are some information categories without a clear preference for or against other specific activity contexts (e.g., identifiers during gaming or lifestyle preferences during world exploration), the heatmap reveals a tendency against disclosure of personal information during other activities than hangouts and intimate get-togethers.

4.7 Technical Channels of Self-disclosure

84 participants provided free-text responses regarding the technical channels they typically use to disclose the information they indicated earlier in the survey. In total, these 84 participants provided 446 responses, from which we derived the categories conversation, avatar, profile, environment, external apps, and media. Figure 9 illustrates relative frequencies of how often the individual categories were mentioned. We assigned answers to several categories when appropriate. A clear majority of responses describe how participants disclose information verbally, i.e., they talk about it. A large proportion of the participants that provided answers specified this

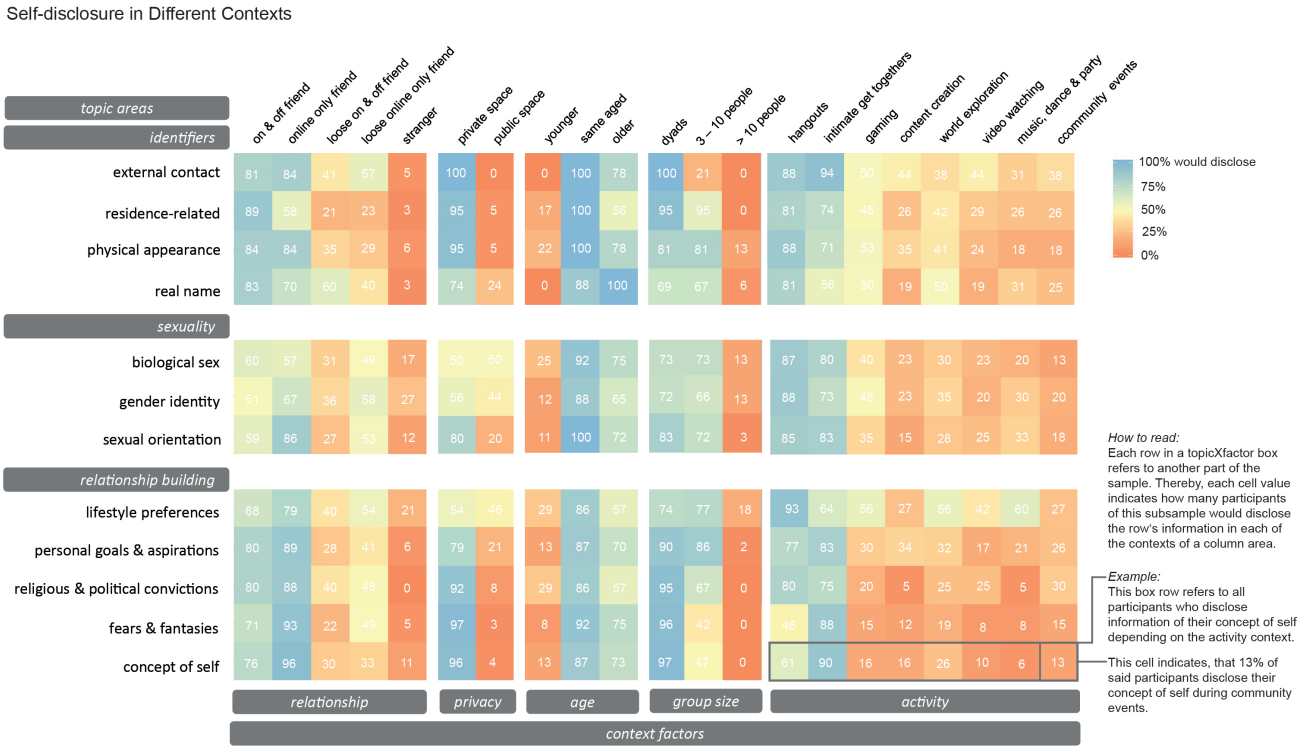

Figure 8: Heatmap that illustrates self-disclosure decisions in different contexts.

and referred explicitly to voice chat, but in some cases also to a conversation via text chat. Still, 16% of participant responses referred to the avatars in general or specific aspects of the avatar system, such as appearance, gestures, and poses, or its locomotion, when describing how they disclose personal information. All other categories of technical channels were only addressed in less than 10% of the responses. These include disclosing information via images and text in user profiles, or via the virtual environment, such as designing it or interacting with specific objects in it. Furthermore, responses occasionally referred to disclosing via external applications, such as *Discord*, *Facebook*, or *Twitter*, and disclosing via sharing specific media such as images or music.

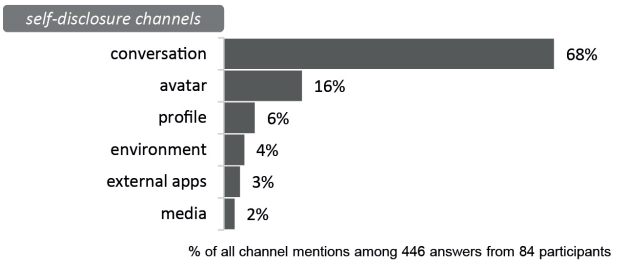

Figure 9: Relative frequencies of the indicated technical channels of self-disclosure.

5 DISCUSSION

Self-disclosure inherently integrates with establishing and maintaining interpersonal relationships. We thus set out to investigate how Social VR users disclose personal information to identify basic patterns of socializing in Social VR. We directly addressed the limitations of previous work on self-disclosure in Social VR with our work. We can now provide broader insights into general opinions on and patterns of self-disclosure behavior in commercial Social VR applications.

5.1 Key Insights

Answering our research questions, we summarize the following main results: **RQ1**: Our results indicate that Social VR provides access to authentic connections with others despite user skepticism and privacy concerns. **RQ2**: We observed that information that breaks anonymity, such as real names, and topics associated with more intimate aspects of oneself, seem to be shared less commonly. Most commonly, sexuality-related information, as well as lifestyle preferences, are disclosed. Though, over a third of users would disclose information related to personal identification, sexuality, and diverse topics of presumably varying degrees of intimacy. **RQ3**:

While different social rewards may motivate self-disclosure in Social VR, relational development and identity clarification seem to be most important for most users. **RQ4**: Accordingly, the relationship to others impacts disclosure-decision of most participants, in particular for topics of higher intimacy and those that break anonymity. However, the privacy of the virtual environment, age of recipients, the group size, and the activity context are also relevant contextual factors that impact the disclosure decisions of at least half of the participants. Further, if participants base their disclosure decision on one of the context factors, they do it in clear patterns. Accordingly, specific contexts where disclosure is most likely to happen are interactions with friends or acquaintances, in private spaces, with same-aged or older people, in dyads or small groups, and during explicitly social activities like hangouts and intimate get-togethers. **RQ5**: Thereby, self-disclosure happens mainly verbally through conversation.

These findings represent, in particular, an extension of insights on self-disclosure in Social VR previously collected in only one study [50]. As most of our participants indicated the relationship to someone as an important influencing factor for self-disclosure, we see the previously described pattern of disclosing depending on familiarity confirmed [50]. This becomes especially clear again in our results on self-disclosure in different types of relationships (Figure 8). Further, as we found the relationship not being equally relevant for the disclosure of different topics (Figure 7), our result also aligns with the pattern described previously, that some participants are open to sharing information with anyone [50], though, we would conclude that this behavior pattern only applies to a minority of users. Similarly, we did not find clear evidence for another pattern described previously: utilizing anonymity for disclosure [50]. While about two-thirds of our participants do not disclose information that would violate anonymity (Figure 5), only the very fewest of those for whom relationship type matters share any information at all with strangers. However, it should be noted that anonymity, e.g. through avatars or usernames, does not directly equate to the degree of familiarity in a relationship (for example, if you have talked to someone several times but still do not know their real name or address). Our results regarding the types of information disclosed also extend findings describing that users disclose personal as well as emotional information [50] by providing a more specific look at what different types of information are being revealed and by how many people. Last, our results also confirm an ambivalent attitude towards self-disclosure in Social VR due to privacy concerns (Figure 4) [50].

The following sections will discuss the individual key insights in more detail and elaborate on the alignment with other related work.

5.1.1 Authentic Connections Despite Skepticism. Our findings align with the previous work that describes Social VR as a medium of authentic social experiences [25, 44, 48, 76, 89]. Moreover, we argue that this general opinion rises from technological affordances that mimic experiential qualities of face-to-face interactions [4, 67, 69]. However, this authenticity is accompanied by skepticism and privacy concerns regarding self-disclosure, which is understandable since authentic information should be more worthy of protection than inauthentic information. Additionally, it could be an expression of interfering perceptions of identifiability and self-presence due to the use of avatar-mediated interaction, which can have beneficial and inhibiting effects on self-disclosure [34]. Accordingly, these concerns may further express the authenticity and emotional value of self-disclosure in Social VR. Following this assumption, the complex interplay between feeling enforced to disclose certain information to use the platform effectively (e.g., voice, movement) and the perceived risk that the platform, or other users, can capture and use this information in unintended ways [50] becomes more significant. Thus, platforms should consider the patterns of self-disclosure behavior identified in our survey to provide users with access to social contexts where they feel comfortable and safe to disclose themselves to others.

5.1.2 Disclosing Lifestyle Anonymously. Our results regarding the limited disclosure of physical **appearance** and **real names** indicate a preference of staying anonymous concerning information that would allow one's identification in the physical world. This preference aligns well with our findings regarding users' skepticism and privacy concerns and previous findings on general patterns of self-disclosure [50]. From a technological perspective, Social VR applications support and encourage a preference for anonymity as they allow the creation and use of custom usernames and avatars that do not necessarily need to reflect their physical appearance or a human at all. Though, considering advances in the creation of photo-realistic avatars that resemble users' physical appearance [62], this may become an interesting future venue for research into user preferences. Further, we see a tendency to keep social interactions inside Social VR based on limited disclosure of **external contact information**. As with the avatar systems that support anonymity, Social VR applications usually provide diverse communication channels that allow for synchronous and asynchronous communication and thus reduce the need for other communication platforms. Further, staying in one ecosystem of communication should also increase the individual control of what personal information may be shared with others. However, it is interesting to note that information related to **residence** (country, region, address) is or would be shared by around 60% of people. Since we did not distinguish between specific residence information, it is ultimately impossible to say what type of information participants were referring to here. However, since the other identifier information is or would be shared by only one-third of the participants, we assume that the participants most likely referred to approximate information that would not easily allow locating a precise residence.

While most participants disclose or would disclose information related to **sexuality**, this is mainly true for cisgender individuals, based on a retrospective look at responses when split by gender identity of participants. In particular, half of the participants who identified as non-binary showed no willingness to disclose this information; this is likely due to concerns of privacy and harassment of this particular group in Social VR [1].

Lifestyle preferences and **personal goals and aspirations** are disclosed by the majority of participants. Based on assumptions of the Social Penetration Theory[2, 14], these findings reflect that,

in particular, information that is usually disclosed early in relationships is disclosed by most participants. This could either indicate that our participants predominantly had younger relationships at the time of the survey, or that Social VR is not a place for deeper relationships or information usually associated with more intimate relationships. Though, given that most participants only have used Social VR for two or one years at the time of the survey, we would assume that our sample is likely to represent in particular users with relationships that had not the chance to last long enough yet. Further, as over half of the participants indicated to disclose information related to their **concept of self**, the most intimate information according to the Social Penetration Theory, some users at least see in Social VR a safe environment for disclosing such information (e.g., due to anonymity), independent from the relationship type. Even if we cannot make any final conclusions on the specific reasons behind disclosure or non-disclosure of certain information, or comparisons to participants' offline self-disclosures, we would interpret our findings as a further indication that Social VR, due to its focus on avatar-based communication, combines characteristics of both, face-to-face and anonymous online-communication [4, 34, 67, 69]: it mimics experiential qualities of face-to-face interaction and how relationships are established there in the course of revealing more intimate information to others, while providing measures of anonymity, that may provoke the disclosure of information types usually shared within long-lasting relationships.

5.1.3 Disclosing for Diverse Social Rewards. Self-disclosure goals can overlap and motivate the disclosure of personal information to different degrees depending on the social situation [61]. We see this assumption confirmed for Social VR but note a slight tendency toward relational development and identity clarification. The relational development goal aligns with insights described in another study that social needs, in particular, motivate Social VR engagement [76]. Further, given that socializing activities like conversations are among the most popular user activities [76] our findings indicate that users satisfy the socializing need by disclosing personal information to others, in particular. Concerning the goal to clarify one's own identity, we also notice alignment with previous findings indicating that next to social needs, needs pertaining to the self also drive Social VR engagement [76]. In addition, previous interviews revealed that the use of avatar-systems in Social VR, especially the customization features, also influence how one perceives and defines oneself [27]. Thus, identity clarification is not only reflected in the use of the avatar-system, which is a defining feature of Social VR [40] but also in the process of self-disclosure based on our results. In addition, self-disclosure in Social VR seems to serve all of the goals queried in the survey, which could motivate the assumption that Social VR users, similar to users of social networking sites, use different platform features to target individual goals [9].

5.1.4 Contexts Moderate Self-Disclosure. All context factors investigated in our survey can be considered relevant for self-disclosure in Social VR. This result is a valuable finding. It illustrates that self-disclosure in Social VR follows specific rules and patterns and results from the interplay of different contextual factors. In particular, the type of relationship stands out as a context factor, as participants coherently consider it relevant for disclosing specific types of information (Figure 7). In contrast, while also relevant for over half of the participants in general, the other context factors do not show crucial relevance for the disclosure of certain information. Though, as all influencing factors considered in our survey were indicated as relevant by at least half of participants, we conclude, that selected impact factors on face-to-face self-disclosure (e.g. relationship, age, group size) [35], moderate self-disclosure also in Social VR. Further, recently investigated key features of Social VR (e.g., private and public worlds, different age groups, various activities) also affect self-disclosure and thus how people socialize.

Our results further allow us to identify how the individual context factors affect self-disclosure decisions. In line with the assumptions of the Social Penetration Theory that self-disclosure is positively associated with the degree of familiarity between people [2, 14] those participants for whom the type of **relationship** to a potential recipient is important are most likely to share information with friends and almost never with strangers. It also aligns with recent findings on the beneficial effects of relational closeness to the audience on self-disclosure in the context of distress disclosure on social media [90]. However, those for whom the relationship is a significant moderator seem more likely to share intimate information with friends and acquaintances whom they only know online. This is not true for identifier information, however. We see this aligning with previous assumptions, that anonymity can have promoting and identifiability inhibiting effects on self-disclosure [34].

Although we did not find indications for **age** being in particular relevant for deciding to disclose specific topics, there are clear patterns of disclosure behavior for those people that base their decision on the recipients' age. Said pattern reflects a preference for revealing oneself to same-aged and older people and is consistent with findings from prior scholarship involving the co-habitation of adults and youths on Social VR platforms [45, 46]. Maloney et al. demonstrated that adults and youth do not always co-mingle well together, affecting what sort of information is disclosed to whom. For example, adults may disclose information that is not age-appropriate for youth or may choose not to disclose information because they feel that youth are listening. This sort of interactivity creates distinct tensions between these two groups, primarily since youth are known to be a large portion of the user base for Social VR platforms [46].

Similar to age, the **privacy**, **group size**, and **activity** context were also not of particular importance for disclosing specific topics. However, if it matters to a person, consistent patterns predict a positive or negative disclosure decision. Thus, regardless of the topics, with few exceptions, private environments, in particular, are used for self-disclosure. In contrast, public environments are only considered for sharing superficial or partly sexuality-related information. Fittingly, predominantly dyads or smaller groups seem to be appropriate contexts, rather than groups of over ten people as often found in public lobby spaces. Activity contexts appropriate for self-disclosure are predominantly explicitly social occasions, such as hangouts or intimate get-togethers. All other contexts explicitly oriented towards other activities, such as gaming or video watching, seem rather inappropriate. Overall, these patterns strongly correspond to the reported skepticism and privacy concerns, and general face-to-face communication strategies for controlling the context

of self-disclosure [20], as they reflect the establishment of dyadic or small group boundaries within private environments [20].

5.1.5 Unused Disclosure Channel Potentials. Our results show that users mainly use the verbal channel, i.e., voice chat features, to disclose personal information, and thus illustrate how Social VR mimics experiential qualities of face-to-face interaction [44, 49, 49, 53, 54, 58, 89]. However, this focus on verbal communication also illustrates a yet to explore space of opportunities for communication affordances beyond what reality has to offer (e.g., augmentation of virtual social interaction) [52, 68, 77]. We suggest that researchers, developers, and users alike should engage in the exploration of that design space to extend opportunities for self-disclosure beyond features already offered by avatar customization in current Social VR applications that promote identity-exploration [27].

5.1.6 Value Beyond COVID?. Eventually, we cannot conclusively assess the potential impact of the COVID 19 pandemic. Although some participants used Social VR more during this time than before, the data tend to argue against the increased importance of self-disclosure in Social VR during the pandemic, thus supporting assuming that our results are representative for times before and after the pandemic.

5.2 Limitations & Future Directions

Our work has several limitations that we reflect on in the following. Due to the applied method as well as recruiting of participants via *Reddit* and similar platforms, the core limitation of our study is a homogeneous sample in terms of the platforms and demographic groups it represents. Further, our recruiting process led to a convenience sample that tends to represent Social VR users who also engage on the platforms where we advertised the survey. Thus, we cannot make any definitive assumption about Social VR users that do not have the following attributes: cis male, from the US or other western cultures, do not use *VR Chat* or *Neos VR*, do not engage on *Reddit* or *Discord*. Further, as the platforms themselves do not publicly share social VR user demographics, we cannot conclusively assess how representative our sample is of the actual population of Social VR users. Though this issue also applies to other Social VR research that uses the same recruiting strategy as we did, e.g., [8, 44, 76], and researchers have yet to find solutions to this problem.

Our results do not provide a comprehensive understanding of all facets of self-disclosure in Social VR but must be considered with the following limitations. As we assessed self-report data outside of Social VR and the subject of investigation, i.e., self-disclosure, our results' validity is limited by participants' ability to reflect on their behavior in Social VR actively. Consequently, we only provide a user-filtered high-level perspective on a series of potentially complex interrelationships. Further, as we mainly used closed-ended questions based on already known concepts from the literature, our results do not provide insights into how self-disclosure in Social VR is based on novel concepts exclusive to this medium (e.g., novel topics, goals, or influencing factors). Thus, our results can only guide discussion of familiar concepts in the context of Social VR. Furthermore, the generical description of categories of topic areas in the survey may have caused participants to have interpreted the categories not as intended. We also did not assess user characteristics beyond demographics and Social VR usage and thus can not conclude the impact of personality traits. These limitations are grounded in the deliberate reduction of survey length and complexity to achieve a greater response rate. As we wanted to reach intrinsically motivated participants, we did not offer any compensation for participation. However, we nevertheless needed to balance the anticipated participant effort, achievable level of detail, and validity of the insights.

These limitations directly translate into suggestions for future work: (1) The collection of data that informs about the demographics of the Social VR user population. (2) Elaborate strategies to assess large-scale samples representing the Social VR user population. (3) Further detailed investigations of specific topic areas and context factors and how they influence individual self-disclosure decisions. It may be valuable to consider methods like ethnographic studies and controlled user studies in Social VR or scientific lab prototypes to decrease dependency on participants' ability to remember and reflect on their behavior while not being in VR. (4) Further, other methods, like ethnographic studies or open-ended questions, may be applied to identify novel aspects related to self-disclosure that can not directly be linked to concepts already known from the literature. (5) Investigate user characteristics and their predictive role for self-disclosure in Social VR. In particular, we currently can not make any assumption about why certain context factors are not relevant for up to 40% of participants or why users deliberately decide against disclosing certain information in Social VR. Additionally, we advocate (6) exploring, designing, and evaluating novel technical self-disclosure channels Social VR offers.

5.3 Implications towards the Metaverse

Currently, large technology companies signal a push towards more *immersive* (e.g., AR/VR) venues for social interaction over a distance that may become the future metaverse(s). Our findings coupled with early scholarship on interpersonal communication, interactivity, and self-disclosure in virtual worlds [10, 23, 28, 32, 33, 50, 85, 88] point towards a few likely trends of the future metaverse(s). It should be noted that these suggestions for the metaverse are ever-evolving and, with new features and technical affordances, may become obsolete soon. We offer these suggestions as to directions for Social VR amid the 2020-2021 global COVID 19 pandemic.

5.3.1 Representation as a Modality for Self-disclosure. Our findings demonstrate that beyond verbal interactivity, one's avatar is the most often mentioned means of self-disclosure. Findings from Maloney et al. also demonstrate the users' connection to the avatar as a form of communication [49, 50]. This trend will likely continue as virtual avatars allow for more dynamic forms of representation and interactivity. For example, Wohn et al. demonstrated that users could adapt and provide ownership towards having additional limbs and non-human bodily configurations [86]. Designers and developers should push interactivity, including self-disclosure, beyond traditional forms of communication (e.g., voice, traditional non-verbal behavior). We emphasize more embodied forms of self-disclosure as some users have been known to prefer avatar-mediated communication [49], which demonstrate that non-verbal communication can afford much more beyond traditional verbal conversation

in Social VR [49, 79]. This key affordance signals toward potentially new forms of interactivity via more nuance use of spatial and avatar-mediated affordances. For example, how can avatar-based communication mediate intimate forms of communication (e.g., self-disclosure) and thus extend affordances of verbal communication? Moreover, what can we learn and extend upon from nonverbal forms of interactivity, which can then inform more immersive forms of nonverbal behavior such as sign language [80]?

5.3.2 Opportunities for Relationship Building in Safe Spaces. The overwhelming majority of our participants referenced the context of relationship as important for self-disclosure in Social VR. Therefore, we suggest that creators of present and future metaverse(s) should mimic opportunities of self-disclosure from the offline world. In particular, we point them towards Rubin et al.'s six factors of interpersonal communication to induce experiences that relate to pleasure, affection, inclusion, escape, relaxation, and control [70]. These experiences, in turn, can be driving factors of relationship-building based on mutual disclosure of lifestyle preferences, personal goals, fear & fantasies, religious & political convictions, and concept of self. Thereby, our results illustrate that users want to establish safe spaces where these experiences can be enjoyed. We thus highlight the importance of providing users with corresponding measures to establish safe spaces for relational development and self-disclosure.

5.3.3 Security & Privacy. Although Social VR mimics the experiential qualities of face-to-face interaction, it raises new challenges for self-disclosure and online privacy, not necessarily associated with face-to-face interactions. For example, in its beta-phase *Meta's Horizon Worlds* included security and privacy measures like "[...] *If you mute, block or report someone, a trained safety specialist, who will not appear as an avatar, may remotely observe and record the situation to ensure your safety.*[...]", or "[...] *which is why your Oculus headset will capture the last few minutes of your experience in Horizon on a rolling basis.*[...]" [55]. The amount of information users can share in a Social VR system is much more than they can through many other sociotechnical systems such as social network sites or online games. For example, Social VR affords the intentional or unintentional sharing of tremendous personal physiological information, including facial features (e.g., through avatar creation or facial tracking), behavioral patterns, and voices. Moreover, as social VR becomes increasingly technical, this will create more embodied forms of communication, creating an additional data source (e.g., motion-tracked data, body movements, gait). This modality provides tremendous opportunity but also risks towards user identification, safety, and privacy. On the one hand, how can this data create and inform more human interpersonal communication? On the other hand, how does it force users to give up biometric data to use the system effectively [50]? Additionally, recent work points towards the identification of user identity up to 95% even when other personally identifiable information is redacted [57]. It also creates ethical dilemmas for users and platforms. For example, can the decision to disclose personal information on a specific platform last forever? Similar to tweets and posts? How and when can this information be deleted? We urge platforms towards transparency in data and privacy controls, which has occurred in other modalities like social media. This will be a crucial pillar in how creators can protect the user integrity of present and future metaverse(s).

5.3.4 Identity & Disclosure Challenges in the Governance. Social VR platforms also face additional privacy and security challenges, specifically linking vs. not linking offline and online identities. The argument for platforms to link one's offline identity is that one's offline identity may be essential in some cases. One example is different forms of mal-conduct on Social VR platforms. For example, Maloney et al. detailed an instance of virtual sexual assault of youth in VRChat [45], with likely little to no punishment for the perpetrator. If user identities were linked to offline identities, these could be disclosed to the perpetrators' local authorities. Yet, the anonymity of most platforms based on online identification via an email address provides distinct challenges for safety, security, and communication on platforms. We suggest a mix of both, linking users' offline identity towards their account and allowing them to choose how they would like to be presented on the platform. Since the users in our study prefer anonymity, we suggest platforms provide universal anonymous avatars that protect the identity of the users, which will still allow for comfort when interacting and communicating online.

6 CONCLUSION

Given that Social VR already provides access to meaningful social experiences over distance, we set out to investigate self-disclosure, one of the fundamental drivers of building and maintaining interpersonal relationships, in commercial Social VR applications. These applications seem to be a venue for authentic disclosure of diverse personal information, where, as in offline communication, the relationship with others moderates self-disclosure in particular. However, our findings indicate that individual self-disclosure decisions can result from complex interactions of different contextual factors that Social VR applications afford. At the same time, users have privacy concerns and seem to value privacy and anonymity in the virtual environment. However, self-disclosure in Social VR benefits relationship building, identity exploration, and other social goals. Considering this, it is essential that the design of Social VR today and in the future addresses user concerns and creates safe spaces for social experiences that match user preferences for specific social contexts. As a starting point, researchers and practitioners can refer to the broader challenges and opportunities for designing the future metaverse(s) that we pointed out.

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A.4. VR Almost There - Simulating Co-located Multiplayer Experiences in Social Virtual Reality

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VR Almost There: Simulating Co-located Multiplayer Experiences in Social Virtual Reality

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Figure 1: We evaluated a VR application that enables two remote users to play a co-located multiplayer game in VR.

ABSTRACT

Consumer social virtual reality (VR) applications have recently started to enable social interactions at a distance. Yet it is still relatively unknown if and to what extent such applications provide meaningful social experiences in cases where in-person leisure activities are not feasible. To explore this, we developed a custom social VR application and conducted an exploratory lab study with 25 dyads in which we compared an in-person and a virtual version of a co-located multiplayer scenario. Our mixed-methods analysis revealed that both scenarios created a socially rich atmosphere and strengthened the social closeness between players. However, the lack of facial animations, limited body language, and a low field of view led to VR's main social experiential limitations: a reduced mutual awareness and emotional understanding compared to the in-person scenario. We derive implications for social VR design and research as well as game user research.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **Virtual reality**; *Collaborative interaction*; • **Applied computing** → *Computer games*.

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KEYWORDS

social virtual reality, multiplayer games, social presence, player experience, social interaction

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1 INTRODUCTION

One of the major purposes of computer-mediated interpersonal communication has always been to enable valuable and rich social experiences at a distance, with face-to-face (f2f) interaction often serving as the gold standard for comparison [8, 68]. When considering modern VR technology, simulating this gold standard and offering an alternative when f2f is not feasible seems possible. Compared to established, non-immersive means of computer-based communication (e.g., videoconferencing), multiuser VR holds enormous potential. It enables natural and intuitive interaction with each other in shared virtual environments using real-time tracking of body movement and its mapping to the virtual world. Current consumer multiuser or social VR applications offer various social- and entertainment-related experiences. Recent research indicates that they provide access to valuable social and other experiences that users integrate into their everyday-life [5, 53, 72, 89]. Additionally, there are significant investments and efforts of large enterprises (e.g., *Meta* or *Microsoft*) into a future "Metaverse" [96] that incorporates virtual environments where people meet and interact with each other through immersive technologies like VR [61, 62]. Therefore, we expect more people to gain access to these experiences in the coming years. However, we believe that people will measure these applications' value more by whether they enable a sufficiently meaningful experience when a physical get-together is not possible, and not whether they induce the same experience as a f2f situation.

As one such scenario, we focus on engagement in co-located or local digital multiplayer games. Playing video games with others in person is still a play mode that many players enjoy [21]. However, modern online multiplayer games feature distinctive benefits such as time- and place-independent scheduling of game sessions [95]. Past studies indicate that unique experiential qualities characterize local multiplayer scenarios—i.e., giving a high-five, seeing the others' facial expression [43, 86] — that result in additional sociability, which remote games often cannot offer due to technical limitations. We see the simulation of co-located multiplayer scenarios in social VR as a promising approach to combine the best of both worlds: (i) eliciting the rich sociability associated with co-located gaming while (ii) keeping the independence of place or distance constraints offered by online games.

This paper presents the design and results of a user study comparing the experiential qualities of playing a digital multiplayer game physically co-located with playing the same game within a social VR environment while being physically separated (see Figure 1). Our work is guided by the following two exploratory research questions:

RQ1: How do the player and social experience in VR compare to the experience in the f2f setting?
RQ2: What features enhance or inhibit the player and social experience in VR?

Comparing the experiential qualities of a virtual and a f2f co-located gaming scenario allows assumptions about how well current and future consumer social VR applications function as an alternative site for meaningful popular leisure social activities when f2f meetings are not feasible. Moreover, our work contributes multiuser VR researchers and practitioners, as well as games user researchers, as follows:

C1: assessing the potential of current social VR offerings to enable meaningful social leisure activities over distance,
C2: extending previous findings from similar use cases by applying more nuanced measures of sociality,
C3: continuing and extending previous research comparing co-located and remote multiplayer game scenarios, and
C4: suggesting research, methodological, and design implications for social VR and games user research.

2 MULTIPLAYER EXPERIENCES

Playing digital games is a widely accepted leisure activity [21] that also provides opportunities for rich social experiences when more than one player is engaged in the gaming context [17, 25, 36, 38, 78, 86]. Prior work suggests that multiplayer gaming can provide a higher level of flow [46] and positive mood [39] than playing alone. In addition to entertainment purposes, many players use multiplayer games to socialize, spend time with their families or friends [21], befriend people they meet in-game [97], or connect with others in exceptional or challenging times [15, 34, 70].

Typically, multiplayer games can be divided into those played while co-located with others and those played online while being physically separated from co-players. With the advancement of technology, online multiplayer games became a common leisure activity throughout society [21]. Compared to co-located games, online games have specific advantages. For instance, players can play games with vast groups of co-players, play against or with strangers, and coordinate game sessions independent from their residence [95]. In contrast, co-located multiplayer games are, per definition, played by players who share the same location. They thus offer more coordination effort in terms of planning time and location of game sessions [95]. Though, as usually played with known others, co-located games tend to be associated with higher enjoyment compared to online games with strangers [95].

More specifically, co-located games benefit from game-external social interactions between players [43, 78, 86] that are not offered by current online games that usually connect players via headsets. Players can physically interact with each other (e.g., high-fives), easily see each others' facial expressions and regulate interpersonal distance. In sum, players benefit from an increased mutual awareness and more interaction opportunities [17], which eventually induce the experience of social presence, i.e.:"sense of being with another" [7]. Early studies comparing different social contexts of playing together indicate that co-located games induce higher levels of social presence, increased fun, and competence feelings [24–26].

However, the authors of these early studies note that physical co-presence alone does not guarantee an enhanced experience. Instead, the interrelationship of factors like players' spatial orientation to each other and the required focus on the game or a shared monitor determine how much players can allocate attention to each other to benefit from the social stimuli present in this scenario [17].

3 SOCIAL VR EXPERIENCES

VR applications that allow multiple users to interact with each other in a virtual world have been developed and researched as immersive, collaborative virtual environments (CVEs [6]) for several decades in varying contexts (e.g., [3, 75, 91, 100]). Today, capable yet affordable consumer-grade VR hardware provides leisure time access to multiuser VR applications that enable private individuals to interact with others worldwide. The genre of consumer social VR applications has emerged since 2015 and currently comprises a range of platforms like *Altspace VR, VRChat, Horizon Worlds*, and *RecRoom*[1] that offer a multitude of activities for social experiences [5, 53, 59, 60, 71, 72, 89], i.a.: socializing with known others and strangers, playing and creating games, dancing, and attending community events.

In social VR, users are commonly represented as avatars through which they interact with the virtual environment and each other. Based on sensory immersion, modern VR headsets induce spatial presence, i.e., the sensation of actually being in the virtual world or the place illusion [82, 98]. In addition, by transferring users' real-time tracked body movements to their avatars, a strong illusion of virtual body ownership can emerge, i.e., a sense that one is embodying the avatar and interacting through it within VR [35, 41, 56, 83]. These building blocks can support social presence and enable intuitive interaction with each other in social VR, including (non)-verbal communication.

Recent work indicates that engaging in social VR may indeed satisfy social, but also entertainment and other needs [89], and can have positive psychological outcomes for users [5], e.g., by supporting meaningful relationships [23, 54, 90, 99]. Other recent studies investigating multiuser VR interaction in general, suggest that social VR can have meaningful social outcomes; compared to f2f interaction, multiuser VR can lead to comparable compliance behavior [19], trust [69], conversation patterns [84], and experiences in a get-to-know-you conversation [74]. But, current social VR platforms still have technological limitations. For example, the tracking of facial expressions, which are the second most important social cue to facilitate social presence following gaze information [81], is not yet an established feature. The hardware required for this has only recently become available for the consumer market and developers have yet to integrate these new capabilities into their applications[2,3]. However, users seem to adapt to such limitations when engaging in social VR regularly and increasingly perceive experiences like social presence [28] or presence [40] over time.

[1]https://altvr.com/; https://hello.vrchat.com/; https://www.oculus.com/horizon-worlds/; https://recroom.com/

[2]HTC released a face tracker in 2022: https://www.vive.com/us/accessory/facial-tracker/

[3]The Meta Quest Pro features integrated face-tracking and was launched while this paper was under review: https://www.meta.com/de/quest/quest-pro/

Since we are interested in replicating a famous use case of joint media consumption in VR (i.e., experiencing co-located gameplay while being physically separated), we specifically searched for work with a similar goal. In total, we found four studies that investigated the following use cases: video watching [57, 63], photo sharing [48], and another study simulating co-located gaming [88].

One study (N=12) evaluated several custom prototypes for shared video consumption using early consumer-grade VR hardware combined with a video-based telepresence setup (e.g., within a lab-based photo-sphere or a virtual cinema) [57]. Overall, the study found that the VR experience can approximate the co-located scenario in certain social aspects depending on the specific implementation. A more recent study (N=22) also compared different setups for watching videos together [63]: f2f vs. social VR (i.e., *Facebook Spaces*) vs. a custom video-based telepresence system using VR headsets and a *Kinect* sensor. The study found that the custom telepresence variant induced a slightly better quality of interaction and more social meaning than the social VR variant. The participants expressed concerns regarding the limited graphical and behavioral realism of the *Facebook Spaces* avatars, i.e., limited facial expressions triggered by controller input and limited body language. However, the overall experience was similar across all conditions.

Another study (N=52) compared photo-sharing experiences in three conditions: f2f vs. social VR (i.e., *Facebook Spaces*) vs. video-conferencing [48]. The social VR version closely approximated the f2f experience with minor significant differences regarding the perceived quality of interaction but no significant differences in social meaning. Again, some participants criticized that the avatars only supported limited facial expressions; these expressions were triggered by controller input, which limited the spontaneity of the emotional reactions.

A work-in-progress paper that examined the same scenario as we do (N=4) only shares anecdotal insights and appears to have not been continued to date [88]. The authors found in their limited investigation that VR seems similar to the f2f scenario. However, based on the anecdotal nature of the work, we cannot derive reasonable conclusions. Nevertheless, the study provides a blueprint for our take on the scenario.

In summary, previous work indicates that VR scenarios of joint media consumption can approximate its f2f counterpart. However, studies in this context are sparse and the setups used do not reflect the capabilities of today's consumer social VR applications. The earliest study [57] does not reflect modern VR hard- and software and did not use avatars. *Facebook Spaces*, that was used in the other studies [48, 63], has been discontinued and the avatar aesthetics used in its successor, *Horizon Worlds*, also evolved. Similarly, the *Oculus Rift S* used in those studies [48, 63] did not support hand and finger tracking and thus limited gestural communication compared to the *Meta Quest* devices that are now available. Further, the studies employed a photosphere of a physical lab as the virtual background [48, 57, 63] instead of a walkable actual virtual environment as offered in today's consumer social VR applications. Unfortunately, there is also no clear information on the duration of interaction [48], or authors opted for a very brief interaction exposure of 2.5 minutes [63], potentially neglecting adaptation effects to avatar limitations [28, 40]. Moreover, the studies predominantly focused on assessing the social experience in terms of perceived

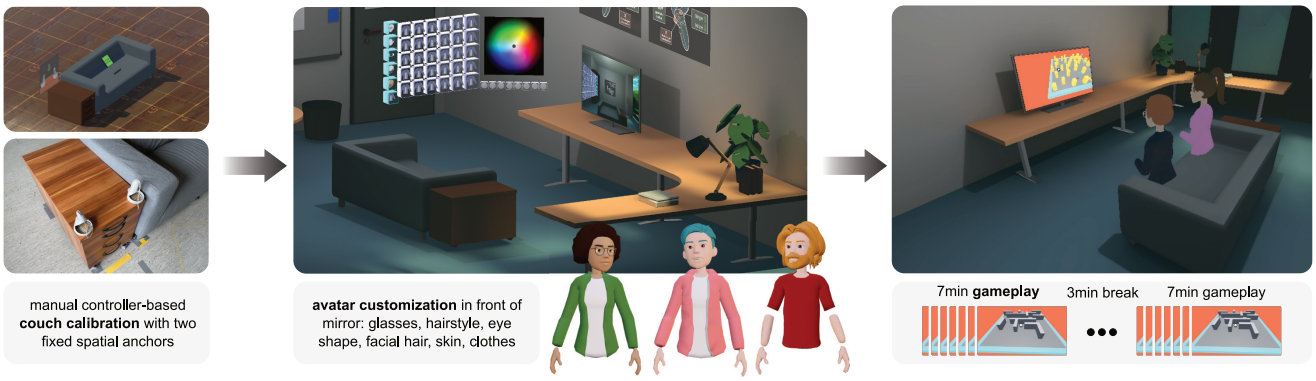

Figure 2: The VR app included three scenes: couch calibration, avatar customization, and the multiplayer scene.

interaction quality, social meaning, and immersion, and mainly report these three aspects [48, 63]. However, other questionnaires, like the Networked Minds Measure of Social Presence (NMMSP) that includes six sub-scales [29], provide a more nuanced assessment of the social experience because it takes more sociality facets into account. Considering those limitations, our work extends the still sparse literature on virtual joint media consumption by providing a timely and nuanced look at our specific use case: simulating co-located multiplayer gaming in social VR.

4 APPLICATION DEVELOPMENT

We want to investigate how well current consumer-grade social VR functions as an alternative site for co-located multiplayer experiences when f2f meetings are not feasible. Thus, our aesthetic goal was not to develop a photorealistic representation of the scenario but a stylized replica whose aesthetic conception resembles current consumer social VR offerings. To compare the VR replica with its f2f counterpart in a controlled lab study, we also had to develop a multiplayer game that we could use equally well in both the VR and the co-located variants with their different input and output modalities. Eventually, we developed two custom applications with the *Unity Engine*[4]: a VR application for the *Meta Quest 2*, a popular, standalone VR headset with integrated hand and finger tracking, and a PC-based multiplayer game to be played on a 55-inch UHD TV screen.

4.1 The Co-located Multiplayer Simulator

We used the following popular social VR applications available on the *Meta Quest 2* as aesthetic references for our VR application: *Rec Room*, *Altspace VR*, *BigScreen*, and *Horizon Worlds*. We also included rudimentary avatar customization, a prominent feature of social VR applications. Utilizing the *Meta Quest 2's* integrated camera-based hand tracking, the application allows users to switch between hand and controller tracking. In this regard, the virtual scenario resembles the physically co-located scenario, as users can also pick up and put away controllers there. Additionally, we implemented a calibration system to match the virtual environment with our physical labs so that physically remote users eventually appear to be sitting on the same sofa in VR. The app uses the VR headset's built-in speakers and microphones to provide voice chat with spatial audio. To ensure sufficient performance, our application relies on a server-client architecture with a PC-based server instance that synchronizes the VR clients. The server instance also provides an audio and video live stream of the users within the VR environment.

4.1.1 Application Structure. As illustrated in Figure 2, our app features three consecutive scenes: a calibration scene, an avatar customization scene, and a game scene in which users meet and play together on a virtual monitor. The app is started while holding the *Meta Quest's* controllers in both hands. These are initially used to calibrate the virtual environment so that the virtual and physical sofas align. As a reference point, we used two spatial anchors on which one places the controllers. Users then use their hands to interact with the virtual world. After the calibration, the users enter the customization scene, where the avatar's arm length, body scale, and appearance can be adjusted in front of the virtual TV display that functions as a mirror. Adjusting arms and body size shall ensure a seamless avatar animation using inverse kinematics. Finally, when both remote users sit on the couch in their individual scenes, they enter the game scene together, appearing as sitting next to each other on the virtual couch. Here, they can retake their controllers to play the multiplayer game together. The game is played in two rounds of seven minutes with a three-minute break in-between. We included the break to provide opportunities for open social interaction in the study.

4.1.2 VR Environment. In contrast to related work [48, 63], we designed a 3D virtual environment that users could explore and that is aesthetically consistent with the avatars we provided. Thereby, the virtual environment's layout and interior match the two same-sized physical labs where we conducted the study. In both labs, we placed the same sofa we rebuilt with the exact dimensions in VR.

4.1.3 VR Avatars. In keeping with the aesthetic language of the selected social VR applications, we created humanoid but stylized avatars with reduced anatomical features (i.e., no legs or feet). Avatars in *RecRoom*, *AltspaceVR*, and *BigScreen* have a torso but lack arms. *Horizon Worlds*' avatars also represent arms. We opted for the middle ground and omitted the representation of the hand joints

[4]Unity 2019 LTS: https://unity.com/releases/2019-lts

and partly the elbow joints (Figure 2), thus preventing visualization of unrealistic joint rotations. Our avatars can be color-customized and individualized with different assets we have prefabricated. All clothing assets are available in a rather masculine or feminine body shape. Assets of different categories can be combined in any way (e.g., a beard with a female body shape and hairstyle). The avatars can represent real-time hand gestures via the hand and finger tracking of the VR headset and thus have increased behavioral realism compared to related work [48, 63]. Further, we implemented simulated blink and pupil movement based on the random fixation of predefined interest points within the avatars' field of view (e.g., nose, eyes, and shoulders of other avatars). Furthermore, mouth animations are triggered by speech input.

4.1.4 Design Rationale for VR Avatars. Despite previously reported concerns regarding avatars with limited graphical realism [48, 63], we opted for stylized avatars. However, in contrast to present them within a real-world photosphere [48, 63], we designed our avatars and the virtual environment aesthetically consistent, preventing potential negative effects of stylistic contrasts within VR. Further, our application provides a longer exposure time compared to the applications in related work. Thus, by allowing our participants to adapt to the stylized but consistent aesthetic of our virtual environment and avatars, we assumed to limit negative reactions to the stylized avatars. However, based on previous findings [48, 63], we decided against including a manual activation of facial animations, which users perceived as burdensome to use [40, 48, 63]. A manual expression system would conflict with the engagement with the multiplayer game. We also rejected an automized approach as reliably triggering different facial expressions based on stimuli like voice input would have required sophisticated algorithms and significantly more nuanced modeling to avoid the uncanny valley and eventually antipathy to our avatars [64, 80]. Moreover, sophisticated simulated facial animations have yet to be an established feature in consumer social VR [93]. Thus, considering that we focus on the overall experience and not the nuances of the avatar system, we did not opt for a facial expression system. Also, past studies indicate that users can acclimate limitations regarding facial emotional expression and recognition in VR if verbal communication is sufficiently supported [40, 65].

4.2 The Co-located Multiplayer Game

In addition to the VR application, we had to develop a multiplayer game that would function equally well in VR on a virtual display and in the co-located scenario on a physical monitor. The game should also be easy to implement as the VR implementation was already extensive. It should run with equal performance in both conditions and be playable with the respective controller peripherals. Eventually, we reviewed game design literature for a game principle that met our requirements to limit conceptual work effort. In particular, we aimed for an easy-to-understand but engaging game mechanic that induces social interaction between players. Thus, we predominantly searched for mechanics to generate player interdependence to motivate player communication [18, 30, 31, 37]. Finally, a recent literature review identified shared control as a mechanic that meets our requirements [73]. It requires multiple players to control the same game object simultaneously and thus generates extreme player interdependence [51, 87]. Since the shared control game described in [87] met all our requirements, we recreated it based on the descriptions in the paper.

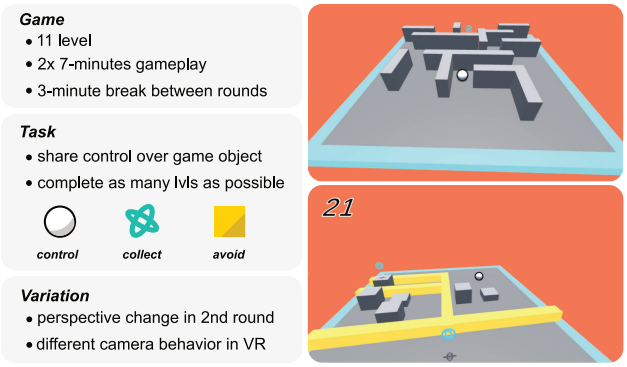

Figure 3: Game design of the shared-control game.

The final game requires two players to navigate a sphere through several obstacle courses. Thereby, the steering input of both players is simultaneously applied to the sphere so that it moves faster if both inputs are similar (see Figure 3). If players do not steer in the same direction, they cannot gain enough speed to overcome certain obstacles in the levels and eventually cannot finish the game. We varied the camera behavior and perspective to introduce more variation for the planned within-participants study design and limit learning effects. For example, in the second round of a condition, the camera perspective changes to the other side of the playing field, so players must now steer in different directions. Consequently, individual levels get implicitly more difficult than before. In addition, the camera behaves differently in the VR version than in the co-located version: camera movement vs. camera panning based on sphere movement.

5 USER STUDY

We compared the co-located multiplayer simulator with its f2f counterpart in a within-participants user study with the two respective conditions *VR* and *Col*. In the *VR* condition, participants played together in VR while being located in separate labs. In the *Col* condition, they were co-located together in the same room and played on a single TV screen (illustrated in Figure 4). Given the sparse literature on joint media consumption in social VR and the identified limitations of prior studies, we opted against a confirmatory approach and did not specify hypotheses. Instead, we conducted exploratory comparisons of the two conditions regarding various facets of the player and social experience (**RQ1**). Further, the study aimed to identify specific aspects of the respective scenarios that promote or limit the social and player experience (**RQ2**).

5.1 Sampling

We applied convenience sampling [4] and advertised the study in lectures of two HCI-related undergraduate and graduate study programs at a university in Germany. The sparse related work on similar study setups did not allow a determination of effect sizes to be expected. We thus did not aim for a confirmatory but an

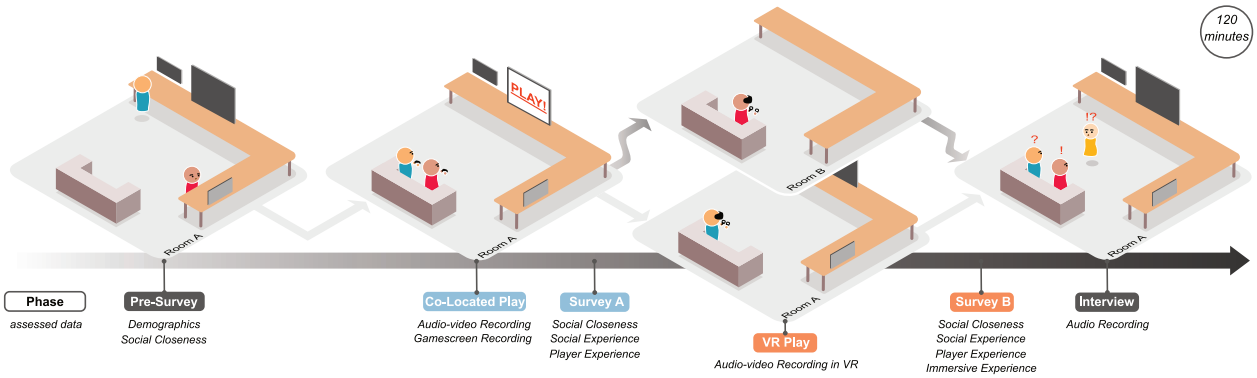

Figure 4: The user study followed a within-participants design with alternated sequence of the co-located and VR play sessions.

exploratory analysis and did not conduct a priori power analysis to calculate a sufficient sample size. Though applying feasibility analysis[5] and aligning with local standards [13] (i.e., comparing to similar studies [20, 30, 48]), we aimed for a sample size of 50.

5.2 Procedure

A study run consisted of four phases and took ca. 120 minutes (Figure 4). At the beginning of the procedure, participants gave their participation consent and agreed with recordings during gameplay and interview. The two conditions were conducted in alternating sequences to counterbalance potential sequence effects.

In the co-located condition, participants played together in the same room, sharing a sofa. After a briefing on the gameplay, a researcher started the screen and camera recording, and left the room. The gameplay lasted 17 minutes, divided into two 7-minute rounds with a 3-minute break. The participants then completed questionnaires in the same room.

Before the VR condition, there was a verbal briefing on the VR headset and application. Afterward, a researcher started the server application and its screen recording in another room. A research assistant then guided one participant into another room. Participants put on their VR headsets in their respective rooms, supported by the researchers. The researchers remotely started the VR applications and guided participants through the first two VR phases: sofa calibration and avatar customization. After ensuring that both participants were in the shared game scene, the researchers left the rooms and met in a third room. Participants again engaged in 14 minutes of gameplay and a 3-minute break. They then completed the PC-based questionnaires alone. During the VR condition, the researchers sat at the server PC that provided a live stream and voice chat of the VR application to intervene in case of technical issues.

Afterward, both participants were interviewed together for 20-30 minutes. Most participants were compensated in the form of certificates of participation if relevant to their study program. There was no other compensation.

5.3 Measures

We used German-translated questionnaires, recordings, and interview questions to assess a broad spectrum of data (Figure 4). Thereby, the questionnaires assessed the player and social experiences in both conditions that we then compared statistically **(RQ1)**. All items of the questionnaires were administered on a 7-point Likert scale (e.g., *Strongly disagree – Strongly agree*)[6]. We used the recordings and interviews to supplement the quantitative data comparison **(RQ1)** and identify explanatory factors for quantitative differences between conditions **(RQ2)**.

5.3.1 Immersive Experience Measures. To evaluate the technical and aesthetic soundness of the VR app, we assessed the immersive experience in the VR condition in terms of the perceived presence, virtual embodiment illusion, and the aesthetic appeal of the virtual environment and avatars. We used the Igroup Presence Questionnaire (IPQ) [79], with its four sub-scales general presence, spatial presence, involvement, and perceived realism. Virtual embodiment illusion was assessed using the ownership and agency scales of the Virtual Embodiment Questionnaire (VEQ) [76]. Finally, we assessed the aesthetic appeal with the audio-visual appeal items of the PXI [1] (regarding environment and avatars).

5.3.2 Player Experience Measures. To evaluate the shared-control game in terms of game design quality and induced player experience **(RQ1)**, we applied the Player Experience Inventory (PXI) and used its subscales perceived mastery, immersion, autonomy, and meaning [1, 27]. For overall game enjoyment, we used three enjoyment items also proposed by the authors of the PXI.

5.3.3 Social Experience Measures. We assessed the social experience **(RQ1)** in terms of three experiential qualities: (i) social presence, i.e., a sense of co-presence and engagement between users [8], (ii) social richness, i.e., the perceived "warmth" of the interaction [50], and (iii) social connectedness as a transformative social outcome. To assess the perceived social presence, we applied the Networked Minds Measure of Social Presence with all its subscales [29]: co-presence, attentional allocation, message and affective understanding, emotional and behavioral interdependence. We assessed social richness using the corresponding sub-scale of

[5] Additional information in the supplementary material.

[6] Anchors varied such as *not at all – very much* depending on the specific instrument.

the Temple Presence Inventory (TPI) [50], which includes seven items of semantic differentials (e.g., unemotional – emotional). Social connectedness was assessed using the Inclusion of Other in Self (IOS) measure [2] consisting of a single pictorial item. Further, participants rated their perceived comfort and feeling of belonging to each other with two items of the friends construct of the Social Connectedness Scale (SCS) [14].

5.3.4 Recordings. To assess participants' social behavior during the gameplay and the break between game rounds, we recorded audio and video of the co-located and VR sessions. These recordings supplement the questionnaire data and provide explanatory information for any identified quantitative experiential differences **(RQ1 & 2)**. In addition, they allow us to check if there were any fundamental technical issues during the sessions, which should be considered accordingly in the analysis. In the co-located condition, we placed a camera next to the TV to record interaction on the sofa. In the VR condition, we only recorded the virtual scenery from several viewpoints within VR.

5.3.5 Interview. We conducted semi-structured interviews with the pairs to gain a more in-depth understanding of the participants' experience and what specific aspects shaped it **(RQ1 & 2)**. The first two authors prepared the interview questions by reviewing, discussing, and refining the questions in detail. The questions were then shared with the rest of the research team to finalize them. Overall, the interview questions were focused on participants' general thoughts on the VR scenario, their perceived sociality during the conditions, their evaluation of the avatars, and their thoughts on using the VR application in their private leisure time.

6 ANALYSIS RATIONALE

In the following, we detail the analysis procedures for the different types of data we assessed in the user study.

6.1 Questionnaire Data

We conducted analyses based on individual participants' scores and initially checked internal consistency for each subscale of the applied instruments. Eventually, we excluded one item from the analysis of the IPQ's spatial presence subscale.

We used frequentist statistics to quantitatively analyze the player and social experience based on questionnaires' subscale data. This analysis comprised subscales' mean and median comparisons between the two conditions. Based on Shapiro-Wilk tests, we checked if the assumption of a normal distribution was met for the participants' score differences. Accordingly, we conducted either paired-sample t-tests or Wilcoxon signed-rank tests. When reporting Wilcoxon signed-rank tests, we report the Hodges-Lehmann estimate, i.e., the median of the individual differences between both conditions ($Mdn_{Pre\text{-}Col}$). Social connectedness scores, which we assessed three times (*Pre*, *Post-VR*, *Post-Col*), were analyzed using a Friedman test and Wilcoxon signed-rank tests for post-hoc pairwise comparisons.

All significance tests were conducted using a .05 α-level (two-tailed). In the case of post-hoc pairwise comparisons, we applied the Bonferroni-Holm adjustment of the α-level [33].

To make our results comparable with those of similar work in the future, we also report effect sizes: Cohen's d for t-tests [16], rank-biserial correlation for Wilcoxon signed-rank tests [94], and Kendall's W for Friedman tests [22]. Additionally, we report 95% confidence intervals for the effect sizes of pairwise comparisons as a measure of their precision.

6.2 Video Data

One of the first authors and the third author conducted the video analysis. A first rough review of the video material revealed that participants' behavior was way more dynamic, complex, and "interesting" during the break compared to the gameplay phase. We thus decided to analyze the gameplay and break phase separately from each other and use different methods for each phase to reduce the analysis effort reasonably. One session was removed entirely from this analysis as participants gave no consent to be recorded during co-located gameplay.

For the gameplay phase, we assessed, with the help of student assistants, instances of socially relevant gaze actions, i.e., one participant looks towards the other. Additionally, we assessed the amount of verbal communication by extracting the accumulated duration of mutually perceivable verbal utterances (e.g., conversation, laughter). These two measures allow us to compare the two conditions in terms of instances in which participants actively perceived each other's presence. One session was removed from verbal communication analysis due to missing audio in the VR condition.

We decided against a quantitative assessment of discrete user behaviors for the break phase analysis. Instead, we opted for an informal qualitative approach, noting and discussing participants' activities and interactions—this process aimed to identify similarities and differences in behavior patterns in the two conditions. Thus, note-taking aimed to provide a focused assessment of social interactions between the participants. The notes were prepared by the third author and then discussed with one of the first authors.

6.3 Interview Data

We transcribed the interviews using automatic transcription[7] followed by manual correction by three native speakers. As we are a multi-lingual team, the transcriptions were then translated to English using translation software[8] and manually corrected for inaccuracies by one of the first authors. Afterward, the two first authors analyzed the interviews, following a hybrid codebook and reflexive method of thematic analysis [11, 12].

In a first phase, we used a codebook-oriented approach to extract some general quantitative insights, e.g., What condition did participants like more? After deciding on initial deductive categories and codes, we started to code the data focusing on participants' general experience evaluation, i.e., were they positive, negative, or neutral about specific aspects? To reduce the time required for this process, each researcher only coded half of the interviews (12 vs. 13). They then reviewed each other's results for disagreements and met to resolve those.

A second phase aimed to reveal how specific aspects of the VR scenario shaped participants' experience. This analysis did not aim

[7] Dovetail: https://dovetailapp.com/
[8] DeepL Pro: https://www.deepl.com/pro?cta=header-pro/

for a final set of codes or agreement on coded paragraphs in the interviews but on inferring coherent themes. We thus applied both aspects of the codebook and reflexive approaches. In particular, we accepted the co-located scenario as the "gold standard". We structured our codes based on this premise, e.g., What aspects inhibited/enhanced the sociality in VR compared to the co-located scenario? How did these affect sociality? Again, we initially constructed deductive categories and codes. We extended these with inductive codes during the analysis. To reduce analysis time, we again decided to split the data set, so the two involved researchers only had to analyze half of the interviews in detail. However, to ensure the validity of the results, both researchers initially synchronized their understanding of initial codes and their perspective on the data by coding three same interviews independently from each other and discussing their results. In this discussion, they did not aim to reach a consensus on the final coding but to extend each others' understanding of the data and use of deductive codes. Only then they did continue independently coding their respective data set (n = 11). Upon completion, they checked each other's non-coded passages in the interviews to prevent information from being missed. They then defined general insights based on their results and presented them to each other. In a final joint reflective discussion, they clustered the insights from the two data sets into coherent themes.

6.4 Reflexivity Statement

The qualitative analysis has been both enriched and potentially biased by the background of the three involved authors [12, 67]. For transparency, we thus specify their backgrounds: One has a background in cognitive systems and psychology and engages in games and VR research. The two others share a computer science and psychology background, with one engaging in multiuser VR research and the other in games user research focusing on social experiences.

7 RESULTS

25 dyads participated in the study (N=50, women=37, men=13, M_{age}=21.74 SD=3.41). All participants grew up in Germany, and almost all were students at the time of the study (n=48). The majority of participants were friends or knew each other well: Fifteen dyads of friends, one of close acquaintances, and one romantic couple. Further, two dyads were loose acquaintances, and four were strangers. Furthermore, in two dyads, participants indicated in-congruent relationship types (in each case, friendship and close acquaintances). Due to this unbalanced distribution of relationship types, we did not consider this factor in further analysis.

Overall, the participants indicated neutral to positive interest (M=4.98, SD=1.80) and passion (M=4.54, SD=1.97) towards digital games and over half (n=35) of them indicated playing at least several hours a month. Prior VR experiences were mostly only made occasionally (n=34) and only one participant had prior experience with social VR applications.

7.1 Immersive Experience

Facets of perceived presence (IPQ), virtual embodiment (VEQ), and audio-visual appeal (PXI) were rated with high scores by at least

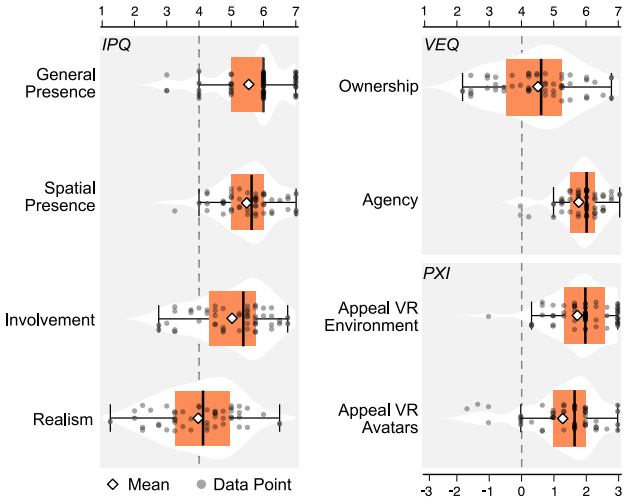

Figure 5: Immersive experience induced by the VR application illustrated by combined box & violin plots with individual data points.

50% and above moderate scores by the majority, as illustrated by median values and interquartile ranges in Figure 5. Participants' scores cover the entire scale for perceived realism and virtual body ownership, and interquartile ranges go below four. But, the median values and violin plots indicate that the bulk of scores is above four. These results indicate a sound technical and aesthetic implementation of the VR application. Thus, we did not consider the immersive experience in the following analysis as a confounding factor.

7.2 Player Experience

All relevant test statistics for the following comparisons are included in Figure 6.

Overall, both conditions seemed to have induced high levels of enjoyment for most participants. No team has finished all game levels; most reached the third-last level. The mastery, autonomy, and meaning scores of the joined gameplay show a central tendency to moderate values across conditions. The perceived immersion seems to have been moderately high in both conditions.

Wilcoxon signed-rank tests revealed significantly higher levels of immersion in VR than in co-located play, but no significant differences concerning enjoyment, mastery, autonomy, and meaning.

7.3 Social Experience

7.3.1 Social Presence. Overall, the participants seemed to have experienced moderate to high degrees of social presence according to central tendencies and distribution of averaged agreement scores of the NMMSP sub-scales, which are illustrated in Figure 7a. The boxplots illustrate larger inter-individual differences regarding the perceived attentional allocation, affective understanding, and emotional interdependency in VR, as scores range from high to rather low values. Further, difference lines, illustrating the participants' individual score differences, indicate inter-individual differences in terms of which condition induced higher levels of social presence.

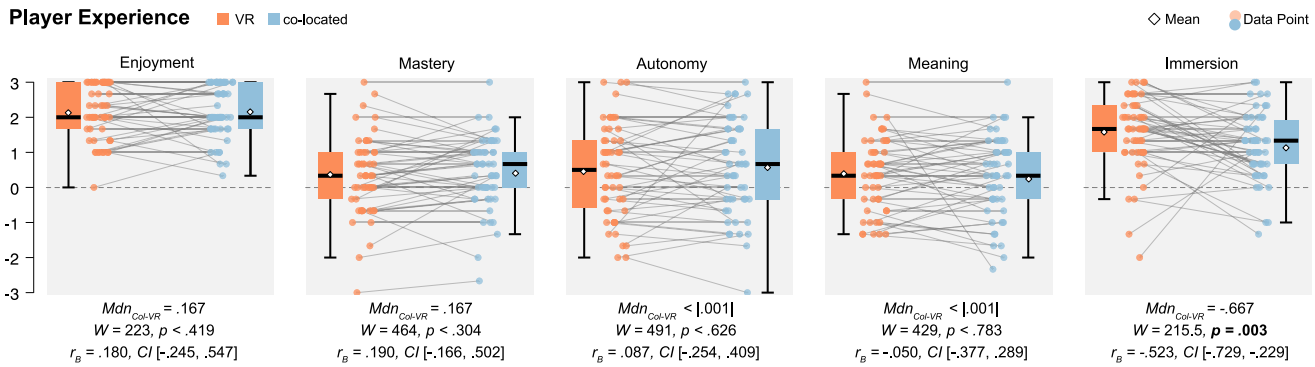

Figure 6: Summary of player experience analysis based on boxplots, individual data points, and test results.

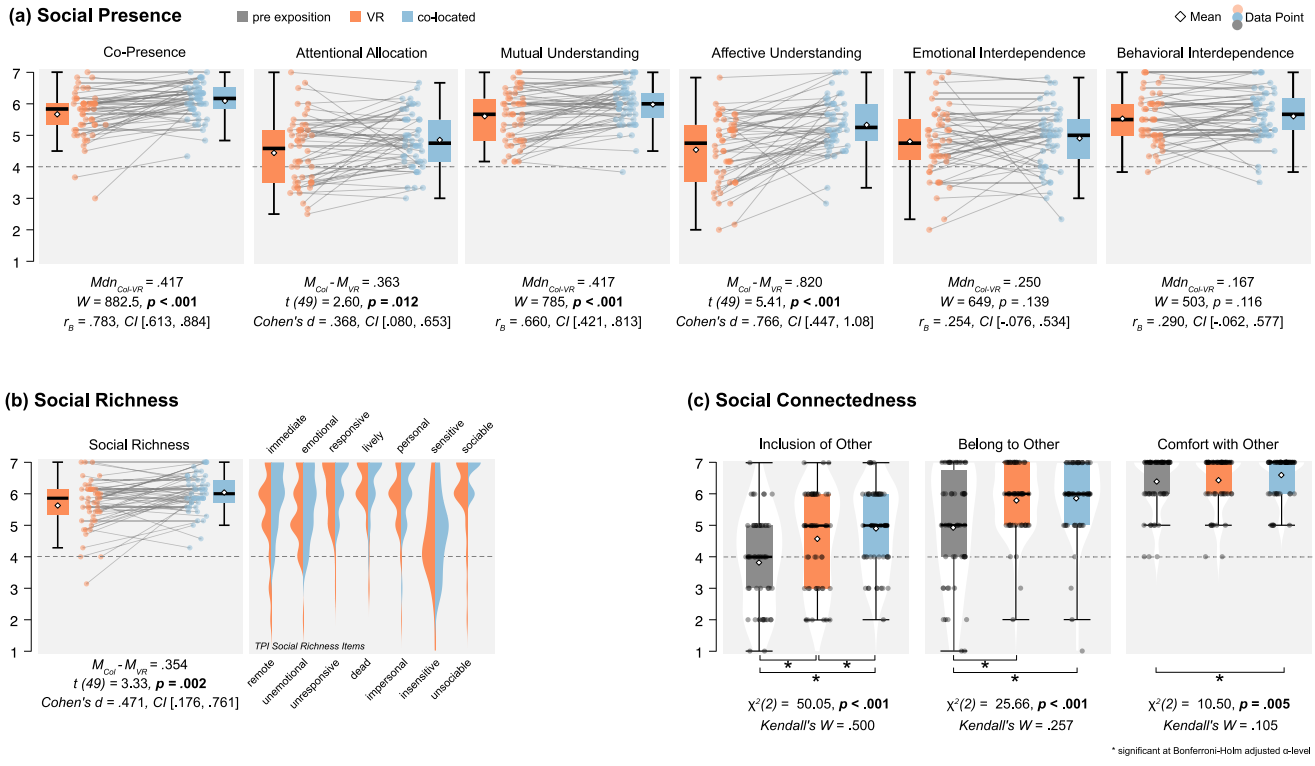

Figure 7: Summary of social experience analysis including individual or combined box- and violin plots, individual data points, and test results.

Wilcoxon signed-rank tests and paired-sample t-tests revealed that perceived co-presence, mutual understanding, attentional allocation, and affective understanding were significantly higher in co-located gameplay. Emotional interdependence and behavioral interdependence were not significantly different in the conditions. All relevant test-statistics are included in Figure 7a.

7.3.2 Social Richness. In both conditions, most participants seem to have perceived high levels of social richness based on how they described the experience using semantic differentials (Figure 7b). Though, social richness was significantly lower in VR than in the co-located condition based on a paired-samples t-test (Figure 7b).

7.3.3 Social Connectedness. The boxplots in Figure 7c indicate that the central tendency of inclusion of other scores changed from a moderate level prior to the gameplay to a slightly increased level after the VR and co-located gameplay. Further, the co-located scores' dispersion seems smaller than the VR scores'. Similarly, the boxplots of belonging scores show a positive change of central tendency from a moderate to a moderately high level and a reduction of score dispersion after gameplay compared to the baseline scores.

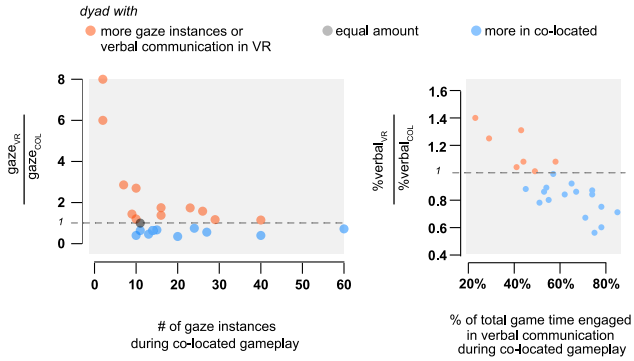

Figure 8: Ratio of social gaze instances and verbal communication amount in VR compared to co-located gameplay.

Perceived comfort of being with the other was high-to-very high at all three measurement times, with some outliers in the moderate level for pre-gameplay and VR measurement.

Three Friedman tests revealed a significant effect of the measurement time (pre vs. VR vs. co-located) on perceived inclusion of other, belonging, and comfort (Figure 7c). Post-hoc analyses with Bonferroni-Holm adjusted α-levels revealed the following significant differences between conditions:

Inclusion of other scored higher after co-located and after VR play compared to study start ($Mdn_{Pre\text{-}Col}$=-1.00, p<0.001, r_B=-1.00; $Mdn_{Pre\text{-}VR}$=-1.00, p<0.001, r_B=-.711). In addition, the scores after the co-located play were higher than after VR play ($Mdn_{Col\text{-}VR}$=1.00, p=0.025, r_B=-.558).

Belonging was perceived higher after co-located and after VR play compared to study start ($Mdn_{Pre\text{-}Col}$=-1.50, p<0.001, r_B=-.746; $Mdn_{Pre\text{-}VR}$=-1.50, p<0.001, r_B=-.764).

The perceived comfort of being with the other was higher after the co-located gameplay than at baseline ($Mdn_{Pre\text{-}Col}$=-1.00, p=0.001, r_B=-.875)

7.4 Verbal & Gaze Behavior during Gameplay

The scatter plots in Figure 8 map the gaze instances and amount of verbal communication within the VR condition's dyads' behavior in the co-located condition. The plots reveal that for the gaze behavior, there was no clear tendency that VR was generally more or less looking at the partner. In about the same number of sessions there were more glances towards the partner in VR as there were sessions in which there were more glances towards the partner in co-located. However, in four dyads with very few attempts to look at the other during co-located play, participants gave each other significantly more partner-directed glances in VR.

Overall, participants tended to engage in more verbal communication in the co-located condition, as the plot in Figure 8 shows more data points representing corresponding dyads. In contrast to gaze behavior, a pronounced influence of the fundamental interaction dynamics in the dyads is evident. The more communicative a pair of participants was in the co-located condition, the more likely they were to be less communicative in VR than in-person.

7.5 Behavior during Co-located Breaks

Most co-located breaks started with a brief game-related conversation. They then drifted either into an off-topic conversation or relatively silent phases of waiting for the break to end. The off-topic conversations, which occurred in half of all co-located breaks, were related to "gaming" in general or to mutual experiences or plans of both participants, e.g., regarding courses at university. Besides, participants who played the co-located game version after the VR version often referred to the VR session, i.e.: they talked about their VR experience and the VR headsets. They discussed both positive and negative aspects of the VR setting (e.g., uncomfortable headsets, VR room feeling comfier). The silent waiting phases occurred in nine sessions. Participants waited seemingly impatiently for the time to pass and felt visibly uncomfortable because they did not know what to say or do. In some of those cases, participants expressed feeling unpleasantly observed by the camera.

During all co-located breaks, participants remained sitting on the couch, looked at each other occasionally while talking, and looked around the room to some extent. Across all co-located breaks, we observed only one instance of social touch. One team performed a high-five at the beginning of the break to celebrate the level they had just won. We noticed no other instances of social touch nor any remarkable gesture-based interaction.

7.6 Behavior during VR Breaks

During the VR breaks, we observed very different behavior. However, the fundamental social dynamics between teammates hardly changed in most cases, as dyads talking a lot in co-located breaks also interacted more in the VR break compared to quieter groups. Predominantly, participants started to explore the interaction possibilities in the VR environment. Except for only eight dyads, the participants tried to touch each other and observed with interest what happened when their avatars collided. Often they started with poking the other's body or face, then trying different forms of physical interaction, including clap games, fist bumps, handshakes, head patting, and boxing. The dominant emotions during such interactions were amusement and fascination, as participants laughed a lot and were curious to try different things.

Most dyads also took a closer look at their avatars during the break. About half of the teams commented on the visual appearances of their avatars, sometimes laughing at eccentric looks (e.g., green hair) or discussing their design choices during avatar customization. Moreover, several participants noted their "missing" legs and wrists, discussing it as strange or irritating. In addition to focusing on their teammates, many participants also explored the VR environment. They moved through the room, looked around, and tried to touch some virtual items and furniture.

7.7 Insights from Interviews

Our first analysis phase revealed the insights illustrated in Figure 9. Around 75% of the participants stated that they liked one of the two conditions better, with almost 50% indicating the in-person variant. Still, about 25% were in favor of the VR version. About 20% of the participants were undecided and could not state a clear preference. The following subsections present results from our second analysis phase and provide detailed insights into the scenario.

Figure 9: Stacked bar charts with percentage distribution of responses to selected interview questions.

7.7.1 ***Theme 1: Most players liked the shared-control game for its simplicity regarding design, controls, and mechanics, which created a motivational pull to proceed.*** Overall, the game was very well received by the players (Figure 9). The shared-control mechanic was well received as the source of coordination and challenge. Though, it was sometimes perceived as annoying or not convincing as a mechanic at all: "*I found it quite funny that both can control everything, but it was equally frustrating.* ". In particular, referring to the later levels of the game, players reported how frustrating it was to fail because of a disproportionally increase in difficulty. A few specifically expressed dissatisfaction with the not-adjustable camera perspective.

7.7.2 ***Theme 2: Avatars and voice chat were the building blocks of the social experience. However, some were unsatisfied with avatars, not only due to technical issues.*** The majority of participants described how they perceived a social presence in the VR condition and how they felt as they were actually sitting next to each other: "*So, it really felt like we were with each other. [...] When I took the glasses off, I was confused for a moment because you weren't in the room with me [...]* "

This was largely related to simply being able to see each other in VR. Many participants emphasized how the avatars fundamentally allow for and signal mutual attention. The mere perception of the other's avatar, its movement through the virtual environment, and its orientation partly induced intense feelings of social presence. Some participants described how they avoided running into each other when taking their controllers. Moreover, during the game, it just felt natural to look to the side and see someone sitting there: "*So the avatar also helped a lot. So that when you looked to the side, you saw someone sitting there.* "

Together, mutual visual perception and the possibility of verbal communication formed the basis for the perceived social presence, naturalness, and emotionality of the interaction in VR. A recurring argument was that one could see and talk to each other just like in the co-located scenario: "*Well, the conditions were relatively the same, because we could see each other somewhere in virtual reality and we could also hear each other.* "

However, some players did not perceive interacting through avatars in VR as natural. They described detrimental effects on sociality in terms of perceived naturalness, social presence, closeness, and emotionality: "*Yeah, well, I think "natural" is hard to say. [...] because in VR it's just an avatar sitting next to you.* "

In individual instances, software-based issues with the avatars were associated with negative effects on the perceived naturalness or realism during the interaction: "*It was sometimes just a little bit with the calibration of the hands, but so that it looked weird for a second, maybe to the other person, but otherwise nothing.* "

7.7.3 ***Theme 3: Avoiding Uncanny Valley and providing customization opportunities can create a pleasant and personal experience, but upper-body-only avatars may annoy some users.*** The graphic style of the avatars was not only predominantly positively received (Figure 9) but was also partially described in the interviews as having a positive effect on the social experience, i.a., by generally contributing to a pleasant atmosphere. Specifically referring to the Uncanny Valley, it was noted by some participants that the style combined a pleasant level of realism with appropriate abstraction so that it did not annoy when looking at each other: "*I think it was pleasant. One didn't get scared now, because you look too realistic [...]* "

In several interviews, participants described how the customization may enhance the personal closeness of the interaction, as customization choices reveal something about themselves: "*[...] it says a lot about the person.* " Further, customization prevents avatars from all looking the same and ensures that they express individualism, which was associated with increased realism. In addition, the design choices induced conversations and triggered mutual laughter in cases of deliberately eye-catching appearances.

For some participants, a match between their interaction partner's physical and avatar appearance can have a positive impact on sociality in terms of the personal closeness, naturalness, or realism of the interaction: "*And of course, they don't look like you, but you can bring them a little bit closer to your appearance, and so you can create a different kind of closeness in VR.* "

In several instances, the anatomical properties of the avatars were critically discussed. In particular, the lack of legs and, in some cases, the lack of wrists harmed the perceived naturalness or realism of the interaction: "*Because it would complete it. It was one of the first things I noticed when I saw him. He has no legs.* " Further, the anatomic limitations of avatars impair opportunities for expression: "*Because half of the body was missing, so to speak. And half of the feelings were also missing, I thought.* " However, a few participants reported that legs were not necessary and they were not annoyed by it: "*It was funny that we were just standing there, just with the upper body, on this couch [...] So it wasn't absolutely necessary.* "

7.7.4 ***Theme 4: Behavioral realism in head movement, body orientation, and gesturing enhanced sociality. However, participants missed mimics and nuanced avatar postures. Social touch in VR emphasized physical separation.*** Most users indicated that sociality was heavily supported by the ability to look at each other and to perceive each others' gaze direction in VR. This, in particular, was supportive during verbal communication: "*[...] it's actually somehow more polite if I then talk and look at her. She sees that, too. And then I thought that was actually relatively natural, yes.*" In particular, seeing that the partner turns his head

and body in one's direction establishes an understanding of mutual awareness. Many participants described this as an essential contributor to their social experience. Despite being limited, the body movement indicated where and in which orientation users sat on the sofa. This way, they could derive rough impressions of each others' attentional state: "*[...] I remember very well this one part where I turned to you and your body was turned to me.[...] I was like: Okay, that's so open and somehow so "turned towards me" and I found that positive.* "

Besides the voice and the avatars' visibility, the possibility to gesticulate with the hands positively influenced the perceived fun, social presence, liveliness, naturalness, and emotionality during social interaction. Gesturing accompanied verbal communication but also allowed gesture-based communication, such as a high-five or a pointing gesture to the virtual monitor: "*But I think the most important thing that I communicated with, apart from my voice, was gestures with my hands.* "

Although limited, the existing facial stimuli of the avatar system were occasionally described as enhancing sociality. Whereas the simulated gaze behavior was not actively recalled, the simulated blinking and the mouth animation during voice input, in particular, were described as increasing the realism and social presence: "*I liked that the mouth moved when you spoke. That definitely supported that the other person was saying something. I also liked it when the avatars blinked, I think they blinked, that it felt a little more natural.* "

In many interviews, the participants described the lack of facial expressions inhibited overall sociality. Some of them specifically referred to the perceived emotionality, social presence, personal closeness, and naturalness: "*[...] but you couldn't see the facial expressions. When someone strains and looks strained. You just didn't notice that.* " In particular, players emphasized how mimics could have enhanced the experience of shared laughter: "*So you also laughed a lot via the headset, but when you see it on the spot, it's something else again, so you feel it even more. Then this sharing of feelings is even more intense.* "

Another inhibitor of perceived emotionality and realism was the lack of nuanced body language, such as detailed body poses. The participants, for example, complained that the avatars could not express the tension during gameplay: "*But you could really see [in co-located] whether the person [...] was suddenly really tense and controlled, that is, was also very concentrated and focused, or somehow played a bit more "laid-back" and chilled out. That has been one of the great aspects, in comparison.* "

Social touch was a social interaction that participants occasionally described as an inhibitor of social presence. In particular, they reported that when a virtual touch happens, but no physical touch is perceived, one becomes aware of the physical distance again. This was further supported by having no visual collisions happening in VR, as avatar models "reached through" each other: " *Except just this obstacle of not feeling each other, even though you still have the visual.* "

However, the participants also relativized the importance of the limitations above. In particular, during gameplay, one tends to focus on the game. Then, limitations such as the lack of facial expressions of the game partner's avatar played a lesser role: "*I don't really think it has an impact because I wasn't looking over at her the whole time [...], I was just looking at the screen and [...] it felt like she was sitting next to me. It doesn't matter what she looks like.* " For some participants, it was also sufficient to hear each others' voices, and thus not a significant issue, that avatars suffered from limited social stimuli: "*I didn't even find the facial expressions absolutely necessary. [...] Because you could take a lot out of the voice, the pitch of the voice, the color of the voice. So how the emotional situation is, how the mood is.* "

7.7.5 ***Theme 5: The majority of participants transferred their relationship dynamics to VR.*** Most participants indicated that knowing the other person was necessary for their overall experience in the VR scenario. For example, knowing their partner's voice and how they look in reality relativized certain avatar limitations. Moreover, knowing each other resulted in isolated benefits for the social and player experience, e.g., a blind mutual understanding while controlling the game was just as possible in VR as in co-located. Further, friends who play a lot together online via voice chat are used to communicate mainly via voice and are adapted to understand each other emotionally in this situation. Furthermore, the majority of participants paraphrased how the usual social dynamics between them transferred to VR: " *Yeah, exactly. So, we were just being ourselves. [...] Like we always are, just not in the same room.* " In individual cases, the participants noted how their behavior and emotions slightly changed in VR, e.g., hitting each other for fun but emphasizing that they would not do this in-person. In another case, the perceived social distance affected the emotional reaction to in-game failure: "*[...] it was just somehow so distant, that it has already stressed me a bit, if it did not work as I wanted in the moment. I didn't have that before [in presence], but then in VR, it made me a little bit angry: Why isn't the ball jumping now?* "

7.7.6 ***Theme 6: Novelty effect of VR, technological aspects, and study design affect sociality.*** The interviews revealed that being in VR enhanced sociality in terms of increased liveliness and enjoyment. This was predominantly attributed to the novelty of VR for many participants. As being one of only few prior experiences or even the first VR encounter at all, the participants reported that this lack of experience stimulated their curiosity and tempted them to interact with each other: "*[...] when we were just on the couch during the break, we weren't really interacting with each other much, [...] But in the VR world, we were there playing around a little bit more, teasing and seeing what you could do [...].* "

However, in some cases, the VR environment distracted participants to the point that they, e.g., engaged less in cooperation or personal conversation: "*Not really, except that in presence, in pause, we talked about something personal. And in VR, we rather tested the limits of the game.* "

The participants saw the 3-minute break as an opportunity for intense social interaction in VR. A recurring comparison was that they did not really interact with each other at all during the break in the co-located scenario, neither did they stand up: "*Yes, yes, with the avatars you also tried to shake hands or something like that. [...] And if you're just sitting on the couch, then, I don't know, only the everyday conversations come up, I would say.* "

One of the prevailing notions of how VR negatively influenced sociality was related to the VR headsets' technical specifications. In particular, due to the restricted field of view, one could not perceive the partner in VR's peripheral field of view. Though, the other

person would still be visible in the exact spatial constellation in the co-located situation. This impaired, especially, the perceived social presence during gameplay: "*But when you're looking straight ahead, you can't see the avatar next to you. But when you're sitting next to each other, you still feel the physical presence of the other person.*"

The condition sequence was occasionally discussed as a sociality-enhancing factor, i.a.: getting used to each other in the first condition and then being more relaxed in the following VR condition, or a decrease of excitement or social focus when transitioning from VR to co-located: "*The first time was just like: cool VR, this is all fun, we're in a game, so let's play. The second time was more: Come on, let's go through the levels now.*"

The study design and context were also occasionally described as limiting certain aspects of the sociality. For example, some participant pairs that did not know each other well noted less social activity in VR, in case it was the first condition because they had yet to warm up to each other. In another instance, a participant had to get used to the study context and the audio-video recording. "*In the first one (VR) you were still rather biased because of....you knew that you were being recorded and that you were being listened to. And so on. And that's the kind of thing you forget at some point [...]*" Further, because of the study context, some participants consciously dispensed crazy avatar designs in the customization, as this would have been inappropriate in the study context.

7.7.7 ***Theme 7: Simulation co-located gaming in VR was accepted by users and found superior to existing options. However, VR technology presents some challenges that require attention.*** Most players could imagine using Couch-Coop VR in their private leisure time (Figure 9), in particular, as it allows them to overcome physical distance and to feel close to friends and family members in specific use cases. In some cases, it was also noted as a convenient alternative to in-person meetings, e.g., when you do not want to drive late in the evening. A few explicitly emphasized that they would have liked to use such an application during the COVID-19's social distancing and quarantine measures.

Most participants evaluated the scenario as superior to current alternatives of playing online games or communicating over a distance. They attributed this mainly to the avatars and the intensified perception of social presence within a spatial context, which induces a more personal experience. Concerning the game experience, some users described how being immersed in VR helped them to focus more on the actual game. Though, a recurring request was that such a scenario must offer a variety of games on the virtual screen. In addition, a few participants hinted that they would like to play a "typical" VR game together and deviate from playing couch-coop games in front of a virtual monitor. Besides that, some participants wished for scenarios or features that would provoke more direct social interactions. Relating to the avatars, the participants would add mimics and legs, as well as more diverse customization features, i.a.: hairs, head-coverings like hijabs, and body shapes.

The interviews also revealed specific challenges and general concerns about using such a scenario or VR technology in the future. Participants mostly noticed challenges due to current technical limitations: blurry view due to limited resolution, a narrow field of view, and bad headset ergonomics regarding weight and fit. They also found it too expensive and worried that it is or will not be widely owned. Further, we identified two general concerns towards VR that were occasionally described: the increased probability of pathological escapism and reduced face-to-face meetings.

8 DISCUSSION

The main goal of our research was to explore how well social VR may function as an alternative to f2f when leisure activities in person are not feasible. We thus determined, in an exploratory user study, how the experience of a co-located multiplayer game scenario replicated in social VR compares to its f2f counterpart. Answering our research questions, we can summarize the following findings.

RQ1: Comparison of Player and Social Experience. In our study, players had a similar player experience in both conditions, with immersion even a bit more intense in VR. In terms of sociality, however, the VR version induced a slightly less rich experience. Furthermore, the VR version generated less co-presence, mutual attention and understanding, and affective understanding. However, we consider the identified differences marginal since both scenarios induced high social richness and social presence overall. Additionally, both conditions increased social connectedness after playing with each other. The qualitative findings show that the participants could transfer their usual relationship dynamics into VR and that most would use the VR scenario privately.

RQ2: Enhancing and Inhibiting Factors. In principle, the shared control game generated social interaction in both conditions. However, in VR, a high level of interaction was particularly evident during the three-minute break. The voice chat and the avatars' presence were essential for the social experience in VR. In addition, avatar customization allowed the introduction of a personal touch, which induced conversation. Moreover, VR generated a high motivation for interaction for novice users. However, we identified specific limitations of the avatar system as the main inhibitors to the social experience: missing lower body and a lack of facial expressions. Those limitations are mainly due to the current tracking capabilities of the *Meta Quest 2*. Similarly, mutual awareness during gameplay in VR suffered from limited peripheral vision compared to human's natural field of view.

8.1 Joint Media Consumption in Social VR

Our results align with and extend previous work that compared f2f and VR interactions in the context of joint media consumption [48, 57, 63, 88].

In the scenarios of joint video watching and photo sharing, VR performed slightly worse in terms of interaction quality than the f2f variant [48, 57, 63]. Perceived interaction quality includes aspects such as mutual attention and perceived emotions [48]. As we applied the NMMSP, which assesses these aspects separately, we can specify previous insights: both aspects are individually less pronounced in VR. However, emotional interdependence did not differ statistically in our setting; even if there were differences in mutual perception between VR and f2f, the users could perceive and reveal so much about each other that they were emotionally interdependent in both scenarios to a similar degree. By looking at our qualitative results, we mainly attribute this to the voice chat that enabled co-players to assess each other's emotions.

The contexts of video watching and photo sharing yielded ambivalent results regarding perceived social meaning in VR compared to f2f. While for video watching, it was lower in VR [63], it was not significantly lower in VR for photo sharing [48]. Social meaning stems from feelings of togetherness, enjoyment, and bonding processes [48]. These components reflect our measures of enjoyment, the inclusion of and belonging to the other, and co-presence. While co-presence and inclusion of the other were marginally lower in our VR condition than in f2f, we found no significant differences in perceived belonging. Thus, our results align with both previous works but give a more nuanced insight. As we assessed social closeness at the study start, we can extend the photosharing results by finding positive social outcomes from collaborative interaction in VR. The differences between ours and others' findings are presumably related to the different spatial orientations of users to each other: facing each other during photosharing vs. predominantly looking at a screen during gameplay and video watching.

8.2 Activity Context Counterbalances Inhibitors

The themes we extracted from interview data align well with previously derived themes, i.a.: avatars with limited behavioral realism due to a lack of or poor implementation of mimics and body language annoyed users, and novelty effect excites users [48, 63, 65]. Though, we extend these by also reflecting on aspects like the role of player relationships, avatar customization, and virtual social touch.

The identified inhibitors in our scenario had limited practical relevance, as we found relatively marginal experiential differences. Co-presence and affective understanding differed most between the scenarios, and we primarily relate these differences to the limited field of view and the lack of facial expressions. As our qualitative findings point out, the participants could not perceive each other within their peripheral view during gameplay, which inhibited their perceived co-presence and attentional allocation compared to the f2f setting. At the same time, specific missing social stimuli did not stand out so much during gameplay as during the break. Though, when actively looking at the partner in VR during gameplay, the lack of mimics and nuanced body postures presumably led to the significant difference in terms of affective understanding and social richness we found. Our qualitative results indicate that these limitations were primarily perceivable during the break, where participants actively interacted with and focused on each other in VR. However, the interaction during the break was again conducive to sociality. In short, the avatars were both facilitators and inhibitors of overall sociality in VR. However, the inhibiting aspects can become less salient depending on the activity context, i.e., playing and focusing on a game together. Additionally, avatar limitations become even less critical if the scenario provides a well-functioning voice chat as the primary source for mutual emotional understanding [40, 48, 65]. We assume that providing a different yet socially stimulating focus point than the avatars is also the main reason previous work in similar contexts found VR to be quite similar to f2f despite using less sophisticated social VR environments [48, 57, 63]. Thus, we infer that joint media consumption is a suitable use case to be replicated in social VR despite its current technical limitations. Moreover, our qualitative analyses highlight that next to the activity context, VR-exclusive features, like avatar customization, create opportunities for social interaction that does not occur in the f2f scenario. In this regard, we consider the break as a crucial design decision supporting our VR scenario's overall sociality.

8.3 Novelty Effects

In line with other studies [19, 48], we also observed novelty effects based on recorded behavior and participant statements in the interviews. Moreover, in our case, they certainly compensated for sociality-inhibiting effects by triggering more social interaction during the game break. However, whether the experience in VR would be significantly worse than in f2f in the long run due to habituation and the omission of novelty effects cannot be conclusively assessed. Recent studies indicate adaptation processes of the users, which may even lead to an increase of individual aspects of the experience over time [28, 40]. Furthermore, as partly desired in the interviews and suggested by related work [48], we emphasize that VR designers should utilize such novelty effects and intentionally deviate from reality [58, 75, 92].

8.4 An Alternative for Socially Meaningful Game Experiences

From a broader perspective, our findings regarding positive social outcomes, i.e., increased social connectedness, align with literature describing the benefits that users already derive from consumer social VR platforms [5, 53, 69, 89]. Our qualitative findings further align with previous observations indicating that existing social dynamics naturally transfer into VR [65]. Consequently, our results also extend the literature comparing different types of multiplayer gaming [24–26] by proposing a new form of online gaming that theoretically allows the interaction aspects particular to local multiplayer scenarios [43, 78, 86] to be experienced in an online context. Thus, our results blur the boundaries between local and online multiplayer, despite certain stimuli, such as mimics, haptic feedback, and body postures, are still limited or missing in our specific VR scenario. However, to avoid undermining the openness to VR technology, we emphasize the importance of adequate software features and interaction designs that compensate for confounding effects that technical limitations may have.

Eventually, we interpret the identified experiential differences as being of low practical relevance in real world use cases, where a f2f meeting is not feasible. Users may experience the social VR variant as slightly different in direct comparison, but we assume it can yet be a sufficient source for social experiences over distance.

8.5 Limitations

Our results are subject to the following limitations. First, they stem from a WEIRD (Western, Educated, Industrialized, Rich, and Democratic) convenience sample [49] and we did not specify a certain population that it may represent. Thus, our results cannot be statistically generalized to a specific population, e.g., all potential future social VR users. However, our exploratory research perspective and findings based on quantitative as well as qualitative data informs more specific follow-up research for extended theory-building [4].

Secondly, the studied scenario particularly thrives on playing it at home in a cozy environment and possibly with more than

two players and varying game modes. Since some participants also mentioned the influence of the study setting as inhibiting, we admit that a lab-based study context cannot easily recreate an equivalent atmosphere. However, given our within-participant design, we assume that the lab setting did affect both conditions similarly. Ultimately, longitudinal in situ research [65] is necessary to assess the real-world value of our VR scenario in different social and game contexts (e.g., compete with remote groups of friends or strangers while being at home) and the extent of assumed habituation and adaptation effects [28, 40].

Finally, as the recently launched *Meta Quest Pro* features integrated face-tracking, follow-up studies may reveal even more similar experiences between VR and f2f. However, costing three times as much as the *Quest 2* and primarily addressing business customers, face tracking may now be an available but also expensive and not yet widely integrated feature. Additionally, the *Quest 2* is currently by far the most popular consumer VR headset[9]. Therefore, we assume our prototype continues to reflect the social VR venues and experiential qualities that most VR users will have access to in the foreseeable future. Thus, our results retain external validity until technological advancements become more economically affordable, widely implemented, and functionally optimized. Also, tracking technologies were not the focus of our research but only one of many factors shaping the overall player and social experience in a specific social VR use case. However, despite technical limitations, our VR prototype already produced an experience very similar to the f2f situation. Accordingly, future studies have to reveal if and to what extent more advanced VR hardware like the *Quest Pro* will enhance the overall experience and how users may reevaluate the lack of features like face-tracking once they have experienced them. Thus, ours and others' findings [48, 63] make a lasting contribution to the field, by demonstrating what current widespread consumer hardware is capable of and by providing a benchmark for evaluating the experiential benefits and user adoption of technological advancements in future studies.

8.6 Social VR Design Implications

We provide the following implications for developers and researchers to design and create compelling social VR experiences based on our results.

As long as VR hardware limitations exist (e.g., the restricted field of view and the lack of face tracking), software solutions should be designed to compensate for inhibiting effects. For example, another user's presence or attention and affective state could be indicated by indicators in the field of view [10, 77].

If relevant in the context, avatars should provide mimics, one of the most important stimuli to contribute to sociality [68, 81]. Since manually triggered facial expressions or emojis can be burdensome [40, 48], approaches that generate facial expressions from intuitive-to-use stimuli like voice or hand gestures seem promising (as is done in *Rec Room* or *Horizon Worlds*. Alternatively, different forms of sharing affective states, e.g., based on biosignal visualization, open up exciting design spaces [47]. However, privacy-related concerns are discussed in recent social VR literature [55, 66, 90]. We thus expect that certain users are not willing to use face or other tracking technologies in individual contexts. For such instances, alternative approaches of manual and automated sharing of affective states should be explored and reconciled with user privacy claims.

We question whether photorealistic avatars based on users' physical appearances are something future users ultimately want or expect in leisure activity contexts. Our qualitative results indicate, in line with other findings, openness for deviations from graphical realism [32, 52, 101]. As existing social VR applications like *VRChat* allow users even to use non-anthropomorphic avatars, ongoing research on the individual contributions of graphical and behavioral realism to a compelling social experience [9, 44, 45, 68, 74, 101] become more practically relevant. In particular, future work should consider how beyond-human avatars that deviate from anthropomorphic traits limit or advance social experiences in social VR encounters. For example, a prior work reported that embodying virtual animals (in a single-user context) induces enjoyment [42], and we believe that social encounters generally could benefit from the mere entertainment values of such approaches. However, we consider the following aspects as factors that might shape social experiences with beyond-human avatars: (i) user preferences and openness to embody and interact with such avatars, (ii) relevance of presented or missing social stimuli (e.g., eye contact) in specific contexts, (iii) presence of intelligible social stimuli, even when presented on graphically non-anthropomorphic avatars (e.g., an animal with human mimics), and (iv) user habituation effects to limited or unfamiliar social stimuli (e.g., exclusively offered stimuli in VR for social interaction like particle effects for high-five interaction [58, 75, 92]). Consequently, avatar design choices should consider the aforementioned factors and how they might stimulate sociality in a specific use case independent from the overall graphical or behavioral realism.

Finally, we are aware that in a real-world use case, users most likely do not have the same room layouts and interior designs as they had in our lab setup. Thus, developers and researchers should continue exploring previous approaches that enable convenient locomotion and interaction within a shared virtual environment that does not inhibit a natural social interaction [85].

8.7 Games User Research Implications

Based on our results, we also define the following implications for games user research.

Shared control demonstrated as a simple yet scalable game mechanic to create high player interdependence and communication. Thus, we recommend it as a mechanic to investigate and promote social dynamics in multiplayer game contexts.

Using VR to simulate co-located multiplayer gaming, where players traditionally sit together, deviates from the paradigm of utilizing VR's spatiality to engage users in walking around. Thus, we see it as a worthwhile scenario for players who do not want or cannot engage in such activity but nevertheless want to play with others over distance in a socially rich manner. Further, this scenario introduces the possibility to experience a previously "friend-exclusive" game situation with strangers and is therefore possibly an access to social dynamics that other game media do not offer so far. Thus, as

[9]Global Headsets Market Share 2022: https://www.counterpointresearch.com/global-xr-ar-vr-headsets-market-share/

a prior work suggests [88], research should further explore this scenario as a novel online gaming context with unique opportunities to not only create innovative experiences but also offer meaningful experiences for players with diverse and individual requirements.

Similar to suggestions from related work, simulating co-located multiplayer in VR, provides a tool for remote testing of co-located games in a standardized environment [88] that inherently provides various opportunities for behavioral observation during gameplay.

9 CONCLUSION

Social VR is a comparatively new communication technology that has yet to prove its capability to provide meaningful social experiences in contexts people value and where in-person encounters may not be feasible. Therefore, we developed a custom social VR application for such a context and compared it in detail with its f2f counterpart: co-located multiplayer gaming. We found that the VR application matched the player experience and closely approximated the social experience of the conventional in-person scenario. However, the lack of facial animations, a limited body language, and a low field of view inhibited facets of the social experience. Our exploratory findings and implications inform follow-up research for extended theory-building regarding the interplay between social VR features, user characteristics, and experiential qualities. In a real-world use case where people may not have the option to decide between VR and f2f, we consider the identified experiential differences as being of low practical relevance and social VR as a source for sufficient social experiences. Consequently, if consumer VR technology advances and becomes more affordable, we anticipate an increasing everyday value of virtual social leisure activities as a means to connect over distance.

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