Towards a Taxonomy of Social VR Application Design

Marcel Jonas
Oakland University
Rochester, MI, 48309, USA
mjonas@oakland.edu

Chris Aiello
Oakland University
Rochester, MI, 48309, USA
cpaiello@oakland.edu

Steven Said Jr.
Oakland University
Rochester, MI, 48309, USA
slsaid@oakland.edu

Nicholas Furlo
Oakland University
Rochester, MI, 48309, USA
nbfurlo@oakland.edu

Daniel Yu
Oakland University
Rochester, MI, 48309, USA
dyu@oakland.edu

Douglas Zytko
Oakland University
Rochester, MI, 48309, USA
zytko@oakland.edu

CHI PLAY EA '19, October 22–25, 2019, Barcelona, Spain

ACM ISBN 978-1-4503-6871-1/19/10.
https://doi.org/10.1145/3341215.3356271

Abstract
The number of social VR applications—or applications that support social interaction between users in virtual reality—has grown considerably in recent years. A consequence of this growth is that the state of social VR application design has become increasingly obfuscated, which complicates identification of design trends, best practices, and uncommon features that are perhaps worthy of wider adoption. To help address this problem, this paper presents a taxonomy of social VR application design choices as informed by 29 commercial and prototypical applications in the literature. Discussion of the taxonomy highlights novel features of research prototypes that could potentially enrich the social experience in commercially available applications. The paper concludes by considering how the taxonomy can guide future design of social VR applications, and next steps for refining the taxonomy.

Author Keywords
Social VR; virtual reality; VR; collaborative virtual environment; taxonomy; social computing

CSS Concepts
• **Human-centered computing~Virtual reality**
• **Human-centered computing~Collaborative and social computing**

Commercially available social VR applications that informed the taxonomy

1. Mozilla VR: a social VR meeting space tool [11, 18]
2. Anyland: Users can manipulate the environment and interact with others [18]
3. High Fidelity: Open world that facilitates social interaction with activities [10, 18-20, 22]
4. VRChat: Open world that facilitates social interaction with activities [18, 19]
5. AltSpaceVR: Open world with interaction between roaming users and environment manipulation [10, 18-21, 27]
6. Rec Room: Open world that facilitates social interaction with activities [18, 19, 21]
7. Facebook Spaces: Private space for Facebook friends to interact [10, 14, 18, 19]
8. vTime: Open rooms in which users can converse around a table [20, 26]
9. Oculus Rooms: Space for interaction with an apartment-like feel [20]

Introduction

For decades the field of HCI has pursued computer-mediated modalities that can support interpersonal communication to the same level as face-to-face interaction. Virtual reality (VR) has been championed as such a modality [3, 22, 28], and the term "social VR" has been used in recent years to label research efforts and applications aiming to support social interaction through virtual space [18, 19, 22]. As social VR research has grown, the state of social VR application design has become increasingly obfuscated. Seemingly straightforward questions such as "how have social VR applications been designed?" are difficult to answer because commercial applications are relatively new, and numerous research prototypes—each with their own unique design—are scattered across the literature.

Developing a taxonomy that organizes social VR application features and their variations can be beneficial to future research and design in several regards. It can help identify trends in application design, as well as uncommon features that may be worthy of (re-)consideration in future applications. Furthermore, associating the design variations in such a taxonomy with empirical research can put a spotlight on the design choices that have received empirical evidence of benefitting social interaction—these can serve as best practices for design. It can also elucidate the design choices that have received little empirical support (i.e., design choices that designers may want to abandon in future applications), and design choices that are in need of further research.

In this paper we present a taxonomy of social VR application features and variations in their design as informed by a review of the social VR literature. This taxonomy represents the initial contribution of a project intended to document social VR application design choices across the commercial and research domains, and then connect those choices to empirical research to identify best practices for design and opportunities for future research.

The Growing Landscape of Social VR Design

Social VR has been defined as "a growing set of multiuser applications that enable people to interact with one another in virtual space through VR head-mounted displays" [18]. While the term "social VR" has become more popular in recent years [2, 8-10, 12, 13, 18-20, 22, 25, 26, 29], the term "collaborative virtual environments" was used similarly in the late 1990s and early 2000s to describe the use of virtual reality to support interaction between two or more users [1, 3].

Research of collaborative virtual environments at the turn of the century involved some novel prototypes [1, 3], and social VR research since 2010 has reported on numerous prototypical VR applications created to explore how particular features support interaction [1-9, 12, 13, 15-17, 24, 25, 28-30]. In addition to this bevy of research prototypes, several commercial social VR applications have been released since 2016 [10, 11, 14, 18-22, 26, 27], which are accessible to the public. Recognizing the need to organize the state of social VR application design, research in the past year has attempted to identify themes in up to seven commercially available social VR applications [18, 19, 21]. However, applications from the research domain have yet to be considered in modern categorizations of features and design possibilities. There are two primary ways for developing a comprehensive taxonomy, or categorization, of social VR application design. One

Prototypical and non-commercial social VR applications that informed the taxonomy

10. IVR Training: VR space for the testing of training efficiency [5]
11. AvatarRealism: Realistic body avatars [13]
12. Classroom VR: Used Comment Mapping to test if students could learn better and become more social in a virtual space [15]
13. Social MatchUP: Users with Neuro-developmental Disorder (NDD) play a game to help their social skills [16]
14. Mannequins: exploration of minimalistic avatars [24]
15. Immersive Deck: Team building exercise [2]
16. Trust Test: Game to test trust with human-controlled and computer-controlled avatars [4]
17. TogetherVR: Photorealistic avatars in a social space [7-9]

involves using the applications directly and documenting their design through first-hand experience. This method lends itself to commercially available applications [18, 19, 21], but excludes those from research that were never intended for public release. Another approach to capture social VR design choices, especially from research prototypes, is to conduct a review of literature that presents or discusses particular applications and their design.

For this paper we crafted a taxonomy of social VR application components and variations in the design of those components as informed by a literature review.

Method

To identify social VR applications to serve as the basis for our taxonomy, we conducted a literature review using the ACM Digital Library, IEEE Xplore Digital Library, Google Scholar, and the Oakland University Library OneSearch (which comprises over 970,000 search materials including journals, books, and conference proceedings). We used the following search terms on each website: social VR, social virtual reality, virtual reality, virtual worlds, Oculus Rift, HTC Vive, and Collaborative Virtual Environment. Five researchers individually reviewed 10 pages of search results for each term per website (a total of 4550 search results reviewed per person). The discovered literature was saved for a full review if the title or abstract mentioned 1) the term "social VR" and/or 2) a VR headset-accessible virtual environment seemingly designed to—or studied in its capacity to—facilitate interaction between users in VR (per definitions of "social VR" [18, 22]). This resulted in a corpus of 39 publications that were fully reviewed to identify any VR headset-accessible applications and features of those applications intended to support interaction between users in VR. A total of 29 applications were discovered from this review. Nine were identified as publicly available/commercial applications in their respective literature (sidebar – page 2), while the other 20 were prototypes intended for research with no indication in the literature of public release (sidebars – pages 2-4). We conducted a card sorting exercise [23] to organize the discovered features of social VR applications and variations in the design of those features. The categories of features were refined through discussions with the research team to produce the taxonomy of social VR design as presented in the next section.

Taxonomy of Social VR Design

The taxonomy of social VR application design is organized into three columns of increasing granularity as one moves right (Figures 1-3). The first column (left) poses three broad aspects of the social VR experience that a given feature is intended to augment: the self, interaction with others, or the environment. For space considerations, we divided the taxonomy into three figures based on these categories. The second column (middle) organizes the features themselves, and the third column (right) organizes variations of those features.

Prototypical and non-commercial social VR applications that informed the taxonomy

18. PrototypingVR: collaborative virtual design/prototyping [12]

19. Holojam (HOLO-DOODLE): painting with others in VR [17]

20. DYNECOM VR: Users communicate with visualized brainwaves [25]

21. Embodied VR: collaborative apartment planning and furniture layout [28]

22. Virtual Dancing: reconstruction of physical-world space in VR [29]

23. The CAVE: room-based VR environment for social interaction [3]

24. ImmersaDesk: projection-based VR environment for social interaction; the user has to be facing the screen with VR glasses to be in the world [3]

Category	Features	Variations of Features
The Self	Avatar Representation	Partial Body Avatars 1, 5-7, 9
		Full Body Avatars 3-5, 8, 10, 11, 14, 16, 17, 19-22, 24, 29
		No Avatar 12, 13, 18
	Avatar Customization	Preset Avatars 1, 3-7, 11, 14, 17, 20, 22, 24, 29
		Appearance Customization 2-9
		No Customization 10, 12, 13, 18-20
	Avatar Manipulation	Full Body Tracking 3-5, 7, 10, 14, 17, 19, 21, 22, 29
		Controller Tracking 1-9, 10, 15, 18, 19, 21
		No Tracking/Minimal 12, 13, 20
	Avatar Traversal	Teleporting 2-8
		Walking 1-6, 9, 14, 15, 22
		No Traversing 13, 20, 29

Figure 1: Taxonomy of social VR features pertaining to the self. Numbers refer to social VR applications in the sidebars. Underlined numbers are prototypical applications developed for research purposes.

Category	Features	Variations of Features
Interaction with Others	Communication Privileges	Muting Other Users 2-8
		Blocking Other Users 1-6, 8, 9
		Adding/Deleting Other Users In Contact Lists 2-6, 8, 9
		Inviting Other Users to Private Worlds 1-9
	Communication Types	Voice 2-9, 10, 13, 15, 17, 21, 26, 28
		Text-Based 12, 27, 28
		Physical Expression 1-9, 10, 14, 19, 21-24, 26, 27, 29
		Visualized Bio-Adaptive Feedback 20
	Activity to Scaffold Interaction	Events 2-5, 13, 15
		Recreation 1-6, 19, 22-25, 27
		Virtual Prototyping 18, 21
		No Activity Scaffolding (Conversation Only) 7-9, 10, 12, 17, 28

Figure 2: Taxonomy of social VR features pertaining to interaction with others.

Prototypical and non-commercial social VR applications that informed the taxonomy

25. TheDomeCityMoo: Participants assume different traits and roles in a VR city [3]

26. Holojam in Wonderland: Immersive mixed reality theater [6]

27. Active Worlds: "Open world" concept for users to enter and exhibit motions of waving, jumping, and dancing. Communication is text-based. [1]

28. OnLive Traveler: Head-only avatars communicate via facial expressions, voice, and text [1]

29. Sync VR: Application for analyzing synchronization and social connection [30]

Category	Features	Variations of Features
The Environment	User Manipulation of Environment	Construct a New Virtual Space 2-5, 27
		Alter Physical Elements 1-6, 9, 10, 13-16, 18, 19, 21, 27
		No Environment Manipulation 7, 8, 11, 12, 17, 20, 22-26, 28, 29
	Spawning Area	Private Area Spawning 2-9, 22
		Social Area Spawning 10, 12-17, 19, 20, 26
	Openness of Environment	Public Environment 2-6, 8
		Private Environment 1-9, 10-29

Figure 3: Taxonomy of social VR features pertaining to the environment.

The self encapsulates features enabling users to control their virtual self, or avatar. Avatar representation refers to how much of a physical human body is replicated in VR. Some applications depict a full body (head, arms, torso, and legs), while some depict a partial body, and others provide no avatar (the user's presence is instead conveyed through manipulation of objects). Avatar customization refers to a user's ability to modify their avatar's appearance (see Figure 4). Applications also vary in how users can manipulate their avatar; some use motion tracking hardware to mimic the user's physical movement in VR, while others enable manipulation through handheld controllers (see Figure 5). Furthermore, social VR applications facilitate avatar traversal, or the transportation of avatars throughout virtual space. Variations include walking and teleportation from one location to another, while some applications prevent the user from changing the location of their avatar at all.

Interaction with others encapsulates features that facilitate interaction between users. Communication privileges refer to ways that a user can control who is able to communicate with them, such as through user-blocking and muting, friends lists, and invitations to interact in private virtual space. Communication types refer to how users communicate. Voice communication through microphones is a common example, and some offer text-based communication through visualized "thought bubbles." Nonverbal communication is also popular through facial expressions (see *TogetherVR* [7-9]), gestures, and other expressions typical of face-to-face interactions (we call these "physical expressions"). A more unique example is bio-adaptive feedback, or the visualization of brain activity and respiration rate as exemplified in *DYNECOM VR* [25]. Some social VR applications scaffold interaction with activities. Some of these activities are events, like public viewings of videos on virtual theater screens (see *AltSpaceVR* [10, 18-21, 27]). Others are recreational activities that require ample avatar movement such as dancing (see *Virtual Dancing* [29]). Another example is virtual prototyping, in which coworkers use virtual tools such

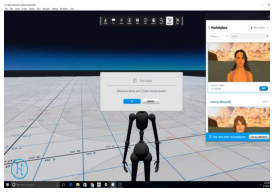

Figure 4: Users in *High Fidelity* can customize their avatar by choosing from a series of preset designs.
"Customizing Avatars 1 – Marketplace Avatars" by High Fidelity is licensed under CC BY
youtube.com/watch?v=6NfiH4rdVRM

Figure 5: Avatar manipulation in *Anyland* is enabled by real-time tracking of handheld controllers.
"LETS PLAY Anyland in VR #1" by Brutal Mootal is licensed under CC BY
youtube.com/watch?v=MrvqxhlDO9E

as pen and paper to collaboratively design and brainstorm (see *PrototypingVR* [12]).

The environment encapsulates design choices of the virtual space through which users interact and present themselves. Several applications enable users to manipulate the environment, such as altering physical elements (e.g., floor plans, furniture; see *Embodied VR* [28]), and creating a new virtual space (see *Anyland* [18]). Social VR applications also vary based on spawning location, or the location at which users enter virtual space. Some spawn users into private rooms accessible only to the individual to help them orient to VR (see *Virtual Dancing* [22]). Others spawn users directly into, or on the periphery of, a location populated with other users. Openness of environment refers to the capability of users to freely traverse different social spaces or rooms, enabling the discovery of strangers (public environments). Private environments, by contrast, allow users to setup virtual rooms that are accessed only with an invitation (see *Facebook Spaces* [7]).

Discussion and Future Work

Now more than ever, social VR is accessible to the masses because of decreasing hardware costs and an array of software applications. It can be easy to forget that social VR prototypes have existed for years and can serve as sources of innovation and inspiration for the future of publicly accessible social VR. Indeed, when compared to descriptions of a select number of commercial social VR applications [18, 19, 21] our taxonomy emphasizes novel design choices from research prototypes that are worthy of consideration in future, publicly accessible applications. For example, visualized brainwaves and respiration rates in *DYNECOM* [25] highlight how bio-adaptive feedback can further augment user interaction beyond the standard voice chat. Likewise, the comment mapping feature in virtual classrooms [15] suggests that text-based thought bubbles could enable multiple users to express themselves simultaneously in a crowded virtual space.

This taxonomy is, of course, a work in progress. Our literature review enabled the identification of several social VR applications, however some may have been missed due to choice of search terms and databases. There likely are several social VR applications (in the commercial domain) not mentioned in scholarly literature as well. Additionally, the social VR applications in our review may include features not mentioned in their respective literature. Future work to expand the taxonomy includes a review of popular literature (e.g., online magazines, blogs) and personal use of a wider array of publicly accessible social VR applications than those already documented.

To maximize the impact of this growing taxonomy on future social VR applications, our future work also involves linking the design choices it categorizes to empirical research that investigates how such features support social interaction. The literature underlying our taxonomy is an excellent starting point, as many of the discussed features were also the subject of empirical study in their respective literature (e.g., full body avatars [28], avatar realism [13]). This linking can identify best practices for design (features with the most empirical evidence of supporting desirable social outcomes), features with little empirical evidence of supporting social outcomes, and uncommon features that are worthy of further research to assess how they augment social interaction.

References

1. Barbara Becker and Gloria Mark. 1998. Social conventions in collaborative virtual environments. *Proceedings of Collaborative Virtual Environments*, 17–19.
2. Wienrich Carolin, IEEE Computer Society. Technical Committee on Visualization and Graphics, and Institute of Electrical and Electronics Engineers. *25th IEEE Conference on Virtual Reality and 3D User Interfaces : proceedings : Reutlingen, Germany, 18-22 March 2018*. .
3. Elizabeth F Churchill, David N Snowdon, and Alan J Munro. 2012. *Collaborative virtual environments: digital places and spaces for interaction*. Springer Science & Business Media.
4. Ceenu George, Malin Eiband, Michael Hufnagel, and Heinrich Hussmann. 2018. Trusting Strangers in Immersive Virtual Reality. Association for Computing Machinery (ACM), 1–2.
5. Ceenu George, Michael Spitzer, and Heinrich Hussmann. 2018. Training in IVR: Investigating the Effect of Instructor Design on Social Presence and Performance of the VR User. 18.
6. David Gochfeld, Corinne Brenner, Kris Layng, et al. 2018. Holojam in wonderland: Immersive mixed reality theater. *ACM SIGGRAPH 2018 Art Gallery, SIGGRAPH 2018*, Association for Computing Machinery, Inc, 362–367.
7. Simon N.B. Gunkel, Martin Prins, Hans Stokking, and Omar Niamut. 2017. Social VR Platform. Association for Computing Machinery (ACM), 83–84.
8. Simon N B Gunkel, Hans M Stokking, Martin J Prins, Nanda van der Stap, Frank B ter Haar, and Omar A Niamut. 2018. Virtual Reality Conferencing: Multi-user immersive VR experiences on the web. *Proceedings of the 9th ACM Multimedia Systems Conference*, ACM, 498–501.
9. Simon Gunkel, Hans Stokking, Martin Prins, Omar Niamut, Ernestasia Siahaan, and Pablo Cesar. 2018. Experiencing Virtual Reality Together. Association for Computing Machinery (ACM), 233–238.
10. Paul Heidicker, Eike Langbehn, and Frank Steinicke. 2017. Influence of avatar appearance on presence in social VR. *2017 IEEE Symposium on 3D User Interfaces, 3DUI 2017 - Proceedings*, Institute of Electrical and Electronics Engineers Inc., 233–234.
11. Jonathan Knispel and Fraser Bullock. 2017. Collaborative VR painting in web browsers. Association for Computing Machinery (ACM), 1–2.
12. Christian Knöpfle. 2009. Working together - a VR based approach for cooperative digital design review. Association for Computing Machinery (ACM), 361.
13. Marc Erich Latoschik, Daniel Roth, Dominik Gall, Jascha Achenbach, Thomas Waltemate, and Mario Botsch. 2017. The effect of avatar realism in immersive social virtual realities. Association for Computing Machinery (ACM), 1–10.
14. Jie Li, Yiping Kong, Thomas Röggla, et al. 2019. Measuring and Understanding Photo Sharing Experiences in Social Virtual Reality. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*, ACM Press, 1–14.
15. Meng-Yun Liao, Ching-Ying Sung, Hao-Chuan Wang, Wen-Chieh Lin, and Fu-Yin Cherng. 2019. Embodying Historical Learners' Messages as Learning Companions in a VR Classroom. Association for Computing Machinery (ACM), 1–6.
16. Tommaso Loiacono, Marco Trabucchi, Nicolò Messina, Vito Matarazzo, Franca Garzotto, and Eleonora Aida Beccaluva. 2018. Social MatchUP -. Association for Computing Machinery (ACM), 1–6.
17. Terrence Masson, Daffy, and Ken Perlin. 2017. HOLO-DOODLE. Association for Computing Machinery (ACM), 1–2.
18. Joshua McVeigh-Schultz, Anya Kolesnichenko, and Katherine Isbister. 2019. Shaping Pro-Social Interaction in VR. Association for Computing Machinery (ACM), 1–12.
19. Joshua McVeigh-Schultz, Elena Márquez Segura, Nick Merrill, and Katherine Isbister. 2018. What's It Mean to "Be Social" in VR? Association for Computing Machinery (ACM), 289–294.

20. Fares Moustafa and Anthony Steed. 2018. A longitudinal study of small group interaction in social virtual reality. Association for Computing Machinery (ACM), 1–10.
21. Seok Hee Oh and Taeg Keun Whangbo. 2018. A study on the effective interaction method to improve the presence in social virtual reality game. *Proceedings of the 2017 4th International Conference on Computer Applications and Information Processing Technology, CAIPT 2017*, Institute of Electrical and Electronics Engineers Inc., 1–2.
22. Tekla S. Perry. 2015. Virtual reality goes social. *IEEE Spectrum* 53, 1: 56–57.
23. Carol Righi, Janice James, Michael Beasley, et al. 2013. Card sort analysis best practices. *Journal of Usability Studies* 8, 3: 69–89.
24. Daniel Roth, Jean-Luc Lugrin, Dmitri Galakhov, et al. *Avatar Realism and Social Interaction Quality in Virtual Reality*. .
25. Mikko Salminen, Simo Järvelä, Antti Ruonala, et al. 2018. Bio-adaptive Social VR to Evoke Affective Interdependence. Association for Computing Machinery (ACM), 73–77.
26. Ketaki Shriram and Raz Schwartz. 2017. All are welcome: Using VR ethnography to explore harassment behavior in immersive social virtual reality. *Proceedings - IEEE Virtual Reality*, IEEE Computer Society, 225–226.
27. John Scott Siri Jr., Hamna Khalid, Luong Nguyen, and Donghee Yvette Wohn. 2018. Screen-viewing Practices in Social Virtual Reality. Association for Computing Machinery (ACM), 173–176.
28. Harrison Jesse Smith and Michael Neff. 2018. Communication Behavior in Embodied Virtual Reality. Association for Computing Machinery (ACM), 1–12.
29. Misha Sra, Aske Mottelson, and Pattie Maes. 2018. Your Place and Mine. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18*, ACM Press, 85–97.
30. B Tarr, Mel Slater, and E Cohen. 2018. Synchrony and social connection in immersive Virtual Reality. *Scientific reports* 8, 1: 3693.