“Hello I am here”: Proximal Nonverbal Cues Role in Initiating Social Interactions in VR

Amal Yassien
amal.walied@giu-uni.de
German International University in Cairo
Cairo, Egypt

Slim Abdennadher
slim.abdennadher@giu-uni.de
German International University in Cairo
Cairo, Egypt

Figure 1: Two users having a conversation in our virtual room with our proximal nonverbal cues. A: a hovering arrow appears when a user gets within the social distance of another user. B: afterwards, a small sound plays when the users become within their field of view (FoV). C: then, conversation partner’s self-assigned name and interests appear for 30s.

ABSTRACT

Virtual Reality (VR) has revolutionized social interactions, but limited field of view (FoV) remains a significant obstacle. Users often fail to notice others within the virtual environment, hindering social engagement. To facilitate initiating social interactions, we developed a novel social signaling technique that utilizes proximal nonverbal cues to indicate users’ location, name, and interests within a social distance. In a 2×2 mixed user study, we found that this technique greatly enhanced social presence and interaction quality among users with prior social ties. Our signaling technique has tremendous potential to facilitate social interactions across various social virtual events, such as staff meetings and reunions.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**.

KEYWORDS

Social VR, Proxemics, Visual Cues, Social Signaling, Social Presence

ACM Reference Format:

Amal Yassien and Slim Abdennadher. 2023. “Hello I am here”: Proximal Nonverbal Cues Role in Initiating Social Interactions in VR. In *Proceedings of the 2023 International Symposium on Wearable Computers (ISWC ’23), October 08–12, 2023, Cancun, Quintana Roo, Mexico.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3594738.3611356

ISWC ’23, October 08–12, 2023, Cancun, Quintana Roo, Mexico

ACM ISBN 979-8-4007-0199-3/23/10…$15.00
https://doi.org/10.1145/3594738.3611356

1 INTRODUCTION

After the pandemic, creating safe and enjoyable social experiences became essential. Virtual Reality (VR) is a prominent candidate, as it provides the illusion of physical co-locality to its users [19, 20]. 25% of the users reported that they socialize in virtual environments (VEs) to experience the sense of Social Presence (the subjective feeling of others being with you in the VE [20]) [33]. To increase social presence, nonverbal cues such as gaze [32] and gestures [38, 40] can be used to transfer user’s behavior from the real to the virtual world. However, there is a research gap in supporting Others’ Presence, the degree of awareness of others’ existence in the VE (see literature review [37]). Although users know that there are other users in the virtual environment, Erickson et al. [4], Williamson et al. [34], and Lee et al. [14] concluded that initiating interactions among small groups is problematic because participants were not noticed by the group members due to the limited field-of-view (FoV) of screens and VR headsets, and participants were not sure how to behave and feared to interrupt an on-going conversation. We fill this gap by designing a social signaling technique using proximal nonverbal cues (proximal cues) within social VEs. Within social VEs, our proximal cues **notify users about the presence of another user within their virtual social distance (<4m)**, as shown in Figure 1. To evaluate how proximal cues impact users’ experience and interaction quality, we conducted a 2x2 mixed design user study with two independent variables: (1) condition (proximal cues present or not) and (2) social tie (known or not). In our experiment, we ensured that participants didn’t know the identity of their conversation partner prior to the experiment. However, participants can identify their partner from their voice, so we considered the effect of social tie (similar to [16]). Our results revealed that proximal cues have increased (1) the sense of realism, social presence, and overall interaction quality among pairs with prior social tie, and (2) novelty (stimulated creativity) among stranger ones. In conclusion, our proximal cues shows potential in facilitating social interactions initiations in social virtual events, like reunions and staff meetings.

2 BACKGROUND AND RELATED WORK

In this section, we relied on social psychology literature to reflect on the presence and social presence theory [19, 20]. Moreover, we reflect on a set of design requirements and guidelines that were extracted from (1) the design space of social presence in VR [37], (2) the design space of cinematic VR [24, 25], and (3) related work.

2.1 Smooth Communications in Virtual Spaces

Presence is the subjective feeling of "being there" in the virtual environment [28]. Schwind [29] and Pan et al. [19] define presence as a function of immersion, where users believe that the virtual environment they are present in is real. Parsons et al. [20] model social presence as a function of intent, with three layers of social presence: Others' Presence (awareness of others' existence), Interactive Presence (awareness of others' interactions towards the self), and Shared Presence (awareness of sharing common global interests). Researchers aim to maximize users' sense of presence and social presence in their VEs by supporting visual-motor synchrony via full-body tracking and representing the users using full-body avatars [37]. Nonverbal cues play an important role in enhancing the social presence of users in the virtual environment [18, 37], and researchers adopt these two different approaches in supporting nonverbal cues in the virtual environment: (1) transferring the users' behavior from the real to the virtual world [17, 32, 39], or (2) augmenting cues that are not present in real environments [23, 25].

2.2 Proxemics Theory and Notification Design

Proxemics Theory identifies four distance classes: public, social, personal, and intimate [7]. Researchers have explored proxemics-based non-VR solutions to improve social interactions among strangers in a public bench setting [12] and facilitate media sharing via natural gestures among co-located co-workers [6]. Also, they have tested the impact of gender [9], scenario, and facial expressions [2] on users' proxemic dynamics in VR, particularly in personal space ones. The key takeaways are that participants' personal space preference in VR was comparable to that in the real world [9, 35], social distance is typically within 4 meters, particularly within virtual spaces [23], distance perception in VR is different than that of the real world [3], and there are five directions where a user can approach a small group of users [2]. To identify the expedient way to transfer the social context while preserving the user's immersion and engagement, researchers investigated the impact of notification design parameters, such as trigger, modality, placement [24, 25]. The results of the below related work guided the design of our proximal cues, where we used the work of Rothe et al. [24, 25] to determine which design aspects to consider in our proximal cues design, and that of Rzayev et al. [26] to determine the optimal placement of our proximal cues (On-body placement). We also relied on the work of (1) Medeiros et al. [15] to determine the most accurate

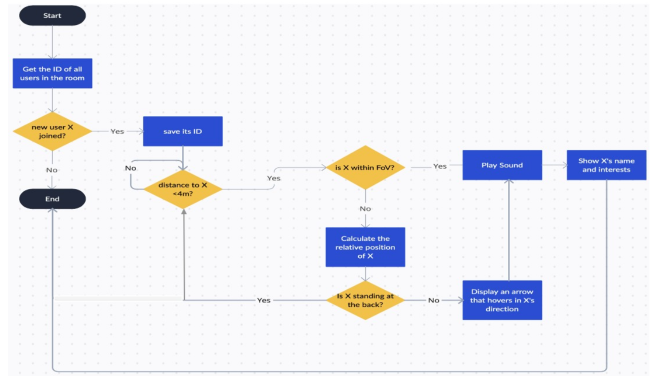

Figure 2: The logic of the script that augments our designed proximal nonverbal cues in the virtual environment.

cue that would help users identify the location of an approaching user (3D arrows), (2) Ghosh et al. [5] to determine the modality of the proximal cues (audio + visual), and (3) Arnold [1] to determine the avatar collider size, preventing personal space violations.

3 USER STUDY DESIGN

We assessed the effect of proximal cues while pairs are engaged in a conversation in virtual reality on (1) the **overall user experience** in terms of presence, social presence, usability, and perceived workload and (2) **interaction quality** in terms of speaking rate, laugh count, and participants' feedback. In our experiment design, we ensured that participants didn't know the identity of their conversation partner before the experiment session. However, it was possible to know the identities of the conversation partner during the session. Therefore, we considered the impact of the participants social relation to one another. We used a 2x2 mixed design study (N = 16, 8 pairs) with two independent variables. (1) **Relation** a between subject variable with two levels, Known and Unknown. The known level represents participants who engaged in social conversation prior to the experiment session, while those who don't are represented using the unknown level. (2) **Condition** a within subject variable with two levels: PC and NPC, where proximal cues are shown in the PC level, and no proximal cues are shown in NPC levels. The order between the levels was fully counterbalanced.

3.1 Apparatus

To properly assess the effect of our proximal cues, we developed a virtual room where pairs enter to have a conversation with each other, as shown in Figure 1. To provide a smooth experience, we supported features that are commonly present in commercial social VR apps. Therefore, we designed full-body tracked humanoid avatars to represent users in the VE. Those avatars lip-sync whenever the user speaks and animate their faces regularly (e.g. blinking). Initially, the users are instantiated in the virtual room in positions where they are out of each others' field-of-view (FoV) and within 4m of each other. Whenever a user enters the social distance of another user (<4m), proximal cues would appear to both users, if the approaching user is not standing behind the other user (similar to [23]). Proximal cues appear before the two users start a conversation, even if the user calls the other, as the other would turn to face the user which would activate the proximal cues. However, the proximal cues appear once per approaching user, as shown in Figure 2. The proximal cues consist of *three* components. (1) An **Arrow** would appear, if the two users are not within each others' FoV to indicate the location of another user in the VE by pointing in his(her) direction, addressing the limited FoV problem. It disappears when the approaching user becomes within the user's FoV or after 15s. (2) A **Sound** would play denoting that a user has successfully found the approaching user, as shown in Fig. 2. (3) A **Text** would display the approaching user's self-assigned interests and name for 30s to provide a conversation starter for strangers and friends. It follows the user's right hand movement, making it easy to dismiss. The arrow and text are placed above the right-hand controller. Also, speaker icons appeared on top of the currently speaking users.

3.2 Implementation

The virtual environment and proximal cues' implementation was based on Unity game engine and composed of six main parts: (1) the avatar design, (2) the hardware setup, (3) the full-body tracking mechanism, (4) the lip-syncing and facial animation mechanism, (5) the networking of the users movements, facial animation, and lip-syncing, and (6) the augmentation of the proximal cues. The avatar was designed using Adobe's Fuse software and rigged using Adobe's Mixamo tool. Our setup was composed of two VR-ready PCs, two Vive headsets, four controllers, and two Jabra Elite Active 45e earbuds, each placed in a different room with a LAN connection between them. For the full-body tracking mechanism, inverse kinematics (IK) was used. 3-point full-body tracking (head + 2 hands) was offered using Rootmotion's Final IK VRIK solver. The lip-syncing and facial animations were supported using Crazy Minnow Studio's SALSA LipSync Suite. The virtual room scene was imported from Super Icon's Lux Room Pack from Unity's asset store. Exit Game's Photon and Photon Voice were responsible for syncing any scene changes and adding a voice connection. A public 3D model for the arrow was used[1]. The arrow points and hovers in the direction of the partner's location. The support of proximal cues was provided through a script (see Figure 2) that is added locally to the user. To protect our participant's privacy, their data were not stored in any database and their values were regularly overridden.

3.3 Procedure

The experiment was conducted in two physical separate rooms, with the participants and the experimenter wearing face masks during the session and semi-structured interviews. The participants were greeted individually, handed a consent form, and introduced to the virtual room. They were asked to conduct a conversation with their partner in the virtual room, once per condition (PC, NPC). The duration of the conversation had an upper limit of 15 mins (to avoid eye strain and cybersickness [31]), and the participants were instructed to conduct the conversation in a manner similar to that of a face-to-face setting and had the freedom to end the conversation at any point before the 15 mins ($M = 8.75, SD = 3.16$). After each condition round, they filled the IPQ [30], Social Presence [21], UEQ [13], and NASA-TLX [8] questionnaires. The experiment session was finalized with a semi-structured interview between the pairs in a single room, where a session lasted for 40-60 minutes.

3.4 Participants and Recruitment

16 university students (5 female, 11 male) were recruited via university mailing list and word-of-mouth with ages between 20 to 28 ($M = 21.97$ years, $SD = 1.83$). 56% had normal visions and 44% had corrected-to-normal ones. They were paired as 4 male-male pairs, 1 female-female pair, and 3 female-male pairs. The number of pairs was balanced with four pairs that knew each other socially and four pairs that were either strangers or know of each other, but never interacted together. 56% had no prior experience to VR before the experiment, 38% used VR 2-3 times, and 6% were experienced.

4 ANALYSIS AND RESULTS

The iGroup Presence Questionnaire (IPQ) [30] and Co-presence and Social Presence from Poeschl et al. [21] were used to measure the user's presence and social presence within the developed social VE. Social Presence is measured in terms of **Interactability** (being aware of others' availability for interaction and understanding each other) and **Co-presence** (existing in the same VE together). The User Experience Questionnaire (UEQ) [13] and NASA-TLX index [8] were used to measure the usability and perceived workload within the social VE. Speaking Rate (Word per Minute, WPM) and Laugh Count were used to measure the user's interaction quality, as they are enjoyment indicators [22, 27]. The count values were obtained after the authors analyzed the recorded videos of the experiment trials and counted the number of words spoken by each participant (fillers (Umm, Ahh) were not counted). The results show the counts for 12 videos (6 trials), as 4 video recordings were lost. Feedback obtained from the semi-structured interviews was also used as a measure of interaction quality. Non-parametric analysis of variance (ANOVA) with aligned rank transform (ART) was administered to analyze the results using Wobbrock's ARTool R library[2] [36]. An interaction contrast, corrected with Holm's sequential Bonferroni procedure was performed on significant interactions.

4.1 Overall Experience Results

Our results show a significant relation × condition interaction across **Realism** ($F(1, 14) = 6.57, p < 0.03, \eta_p^2 = 0.32$), **Interactability** ($F(1, 14) = 5.32, p < 0.04, \eta_p^2 = 0.28$), and **Novelty** ($F(1, 14) = 5.75, p < 0.031, \eta_p^2 = 0.30$) rates, where users in the PC-Known (PC-K) felt that their experience was more realistic ($\chi^2(1, 16) = 6.57, p < 0.011, M_{pc-k} = 3.88, SD_{pc-k} = 0.85, M_{npc-k} = 3.25, SD_{npc-k} = 0.57$) and interact-able ($\chi^2(1, 16) = 5.32, p < 0.022, M_{pc-k} = 5.52, SD_{pc-k} = 0.52, M_{npc-k} = 4.80, SD_{npc-k} = 0.77$) than the NPC-Known (NPC-K). However, they felt that their experience was more novel in the PC-Unknown ($\chi^2(1, 16) = 5.75, p < 0.017, M = 1.38, SD = 1.03$) than they did in the PC-Known ($M = 0.84, SD = 1.33$). Also we report a main effect of Condition on Mental Demand ($F(1, 14) = 6.06, p < 0.03, \eta_p^2 = 0.30$) and Relation on **Physical Demand** ($F(1, 14) = 8.69, p < 0.02, \eta_p^2 = 0.40$), where participants experienced higher **Mental Demand** in the PC condition ($M =$

[1]https://clara.io/view/b8a8fb8d-cfe7-4e5d-a219-e26f862feb42

[2]https://depts.washington.edu/acelab/proj/art/

45.94, $SD = 26.53$), than they did in the NPC one ($M = 29.69, SD = 21.33$) and known pairs ($M = 41.25, SD = 23.91$) reported more physical demand than unknown ones ($M = 21.56, SD = 13.51$). However, insignificant change was observed in Involvement, Presence, Spatial Presence, Co-presence, Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, Temporal Demand, Performance, Effort, Duration, and Frustration.

4.2 Interaction Quality Results

4.2.1 Speaking Rate and Laugh Count. The Speaking Rate and Laugh Count were calculated from 6 pairs, as two videos recordings were lost, where 3 pairs know each others and 3 pairs do not. The gender pairing was: 3 male-male, 2 male-female, and 1 female-female. We observe a significant crossover Relation × Condition interaction on **Speaking Rate** ($F(1, 10) = 5.85, p < 0.04, \eta_p^2 = 0.37$) and **Laugh Count** ($F(1, 10) = 5.31, p < 0.05, \eta_p^2 = 0.35$), where known pairs laughed more ($\chi^2(1, 12) = 5.31, p < 0.022, M_{pc-k} = 10.17, SD_{pc-k} = 6.18, M_{npc-k} = 7.67, SD_{npc-k} = 4.18$) and talked faster ($\chi^2(1, 12) = 5.69, p < 0.018, M_{pc-k} = 33.88, SD_{pc-k} = 6.97, M_{npc-k} = 25.35, SD_{npc-k} = 6.42$) in the PC condition.

4.2.2 Semi-Structured Interview Feedback. We report on the general participants' feedback obtained from the semi-structured interviews conducted after each experiment trial and general observations obtained from analyzing the videos. Participants reported that they enjoyed using the prototype "It was nice to stand this close to someone without worrying about COVID" (P1) and noted the presence of proximal cues "I followed the arrow direction because it hovers in front of me" (P3), and "I read the text because it keeps following my hand direction which I haven't seen before" (P9). Proximal cues helped known pairs discover their own interests "I saw the text saying that P7 likes movies and I was astonished because I didn't know he liked them" (P8, knew each other) and helped unknown pairs get to know each other "I relied on the interests provided in text to get to know my conversation partner" (P5, didn't know his conversation partner). The experimenter noticed that familiar pairs were engaged and immersed in a friendly banter to the point that they forgot the shape of the physical room. Additionally, familiar pairs tended to (1) follow up on their common friends or talk about events that happened during this day, (2) play games that involve movement, and (3) explore the environment. Pairs who didn't know one another tended to focus on getting to know one another. However, a pair of strangers (P13, P14) played rock, paper, scissors by coding movements for rock, paper, scissors (crossing, stretching, and shaking their arms).

User Experience		Interaction Quality	
Realism Interactability	PC >NPC for known pairs	WPM	PC >NPC for known pairs
Novelty	PC >NPC for unknown pairs	Laugh Count	
Physical Demand	Known >Unknown	Interview Feedback	Known pairs: -reconnected and caught up -PC made them discover their partner interest
Mental Demand	PC >NPC		Unknown pairs: -relied on PC to get to know their partner

Table 1: Summary of the results of the dependent variables that showed statistical significance and interview feedback.

5 DISCUSSION AND IMPLICATIONS

Proximal Cues Enhance Social VR Interactions among Familiar Pairs. Proximal cues enhanced users' realism, social presence, speaking rate, and laugh count, promoting re-connection, catching up, and gaming among pairs with prior social tie. However, they slightly increased mental demand ($M_{PC} = 46, M_{avg} = 42$) [3], but the mental demand score were within the standard range. We hypothesize that proximal cues enhance realism and social presence for familiar pairs because they provide proof of their partner's identity through name and interests, increasing the social connection among the pair. Since proximal cues showed potential in facilitating VR interactions, they can be scaled to notify about approaching groups.

Social Ties influence the Design of Proximal Cues in VEs. Social tie among conversation pairs affects performed activities and response to proximal cues within the VE. Familiar pairs focus on exploring the environment's features, enhancing their experience and interaction quality. Although, proximal cues were utilized by stranger pairs and stimulated creativity among them (e.g. inspired them to create new games), they distracted them from their conversation partner. For instance, the text denoting interest lasted for 30s only at the beginning of the conversation. Thus, we hypothesize that the pairs were more focused on recalling the other's interests than they were on the conversation itself. Therefore, we can consider having the text cue reappear and vanish by the user whenever needed. Also, overt cues overwhelmed them, as they are meeting new people in a new environment. Therefore, the effect of subtle proximal cues should be considered.

Proximal Cues and Social Interactions using Wearable Computers. Our proximal cues could act as a **virtual assistant** to party-goers or executives by displaying data about approaching users (name, interests, their latest social news) on a wearable device, aiding social interaction initiation in real-world social events similar to Jouet et al's [10] AR blue-tooth based chat application. Therefore, our designed proximal cues could extend to wearable computers, like smart glasses, smartphones, and smartwatches. However, ethical and privacy implications and social acceptance should be investigated and considered [11].

6 CONCLUSION

Proximal cues were designed to aid in initiating social interactions in VR via addressing the issues of hesitation to approach a group or not noticing the approaching user due to the limited field-of-view (FoV). Our results showed that proximal cues increased users' social presence, realism, and interaction quality among familiar pairs. The social tie affected the *activities* that users perform within the VE and users' *response to our proximal cues*, leading to higher physical demand among familiar pairs and increased novelty (i.e. stimulated creativity) among stranger ones. Our findings show that our proximal cues can enhance the users' sense of others' presence when the interacting users have prior social relation. However, different proximal cues design choices are needed to aid social interactions among strangers. Our work enhances the quality of communication and interactions within virtual social events on personal and professional capacities, like reunions and staff meetings.

[3]https://measuringu.com/nasa-tlx/

REFERENCES

[1] Peter Arnold. 2017. You Better Eat to Survive! Exploring Edible Interactions in a Virtual Reality Game. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. ACM, Association for Computing Machinery, New York, NY, USA, 206–209.

[2] Andrea Bönsch, Sina Radke, Heiko Overath, Laura M Asché, Jonathan Wendt, Tom Vierjahn, Ute Habel, and Torsten W Kuhlen. 2018. Social VR: How Personal Space is Affected by Virtual Agents' Emotions. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, Institute of Electric and Electronics Engineers, New York, NY, USA, 199–206.

[3] Zubin Choudhary, Matthew Gottsacker, Kangsoo Kim, Ryan Schubert, Jeanine Stefanucci, Gerd Bruder, and Gregory F Welch. 2021. Revisiting Distance Perception with Scaled Embodied Cues in Social Virtual Reality. In *2021 IEEE Virtual Reality and 3D User Interfaces (VR)*. IEEE, Institute of Electric and Electronics Engineers, New York, NY, USA, 788–797.

[4] Thomas Erickson, N Sadat Shami, Wendy A Kellogg, and David W Levine. 2011. Synchronous interaction among hundreds: an evaluation of a conference in an avatar-based virtual environment. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Association for Computing Machinery, New York, NY, USA, 503–512.

[5] Sarthak Ghosh, Lauren Winston, Nishant Panchal, Philippe Kimura-Thollander, Jeff Hotnog, Douglas Cheong, Gabriel Reyes, and Gregory D Abowd. 2018. NotifiVR: exploring interruptions and notifications in virtual reality. *IEEE transactions on visualization and computer graphics* 24, 4 (2018), 1447–1456.

[6] Jens Emil Grønbæk, Mille Skovhus Knudsen, Kenton O'Hara, Peter Gall Krogh, Jo Vermeulen, and Marianne Graves Petersen. 2020. Proxemics beyond proximity: Designing for flexible social interaction through cross-device interaction. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–14.

[7] Edward Twitchell Hall. 1966. *The hidden dimension*. Vol. 609. Garden City, NY: Doubleday, New York, NY, USA.

[8] Sandra G Hart. 2006. NASA-task load index (NASA-TLX); 20 years later. In *Proceedings of the human factors and ergonomics society annual meeting*, Vol. 50. Sage publications Sage CA: Los Angeles, CA, Sage publications Sage CA, Los Angeles, CA, USA, 904–908.

[9] Tina Iachini, Yann Coello, Francesca Frassinetti, Vincenzo Paolo Senese, Francesco Galante, and Gennaro Ruggiero. 2016. Peripersonal and interpersonal space in virtual and real environments: Effects of gender and age. *Journal of Environmental Psychology* 45 (2016), 154–164.

[10] Pierrick Jouet, Vincent Alleaume, Anthony Laurent, Matthieu Fradet, Tao Luo, and Caroline Baillard. 2020. AR-Chat: an AR-based instant messaging system. In *2020 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*. IEEE, Institute of Electrical and Electronics Engineers, New York, NY, USA, 153–157.

[11] Michael Katell, Francien Dechesne, Bert-Jaap Koops, and Paulus Meessen. 2019. Seeing the whole picture: visualising socio-spatial power through augmented reality. *Law, Innovation and Technology* 11, 2 (2019), 279–310.

[12] Sofie Kinch, Erik Grönvall, Marianne Graves Petersen, and Majken Kirkegaard Rasmussen. 2014. Encounters on a shape-changing bench: exploring atmospheres and social behaviour in situ. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction*. Association for Computing Machinery, New York, NY, USA, 233–240.

[13] Bettina Laugwitz, Theo Held, and Martin Schrepp. 2008. Construction and evaluation of a user experience questionnaire. In *Symposium of the Austrian HCI and usability engineering group*. Springer, Springer Berlin Heidelberg, Berlin, Heidelberg, 63–76.

[14] Chiwon Lee, Hyunjong Joo, and Soojin Jun. 2021. Social VR as the New Normal? Understanding User Interactions for the Business Arena. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI EA '21)*. Association for Computing Machinery, New York, NY, USA, Article 420, 5 pages. https://doi.org/10.1145/3411763.3451740

[15] Daniel Medeiros, Rafael dos Anjos, Nadia Pantidi, Kun Huang, Maurício Sousa, Craig Anslow, and Joaquim Jorge. 2021. Promoting Reality Awareness in Virtual Reality through Proxemics. In *2021 IEEE Virtual Reality and 3D User Interfaces (VR)*. IEEE, Institute of Electrical and Electronics Engineers, New York, NY, USA, 21–30.

[16] Fares Moustafa and Anthony Steed. 2018. A longitudinal study of small group interaction in social virtual reality. In *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*. ACM, Association for Computing Machinery, New York, NY, USA, 22.

[17] Dooley Murphy. 2017. Building a hybrid virtual agent for testing user empathy and arousal in response to avatar (micro-) expressions. In *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology*. ACM, Association for Computing Machinery, New York, NY, USA, 50.

[18] Catherine S Oh, Jeremy N Bailenson, and Gregory F Welch. 2018. A Systematic Review of Social Presence: Definition, Antecedents, and Implications. *Front. Robot. AI 5: 114. doi: 10.3389/frobt* 5, 114 (2018), 35 pages.

[19] Xueni Pan and Antonia F de C Hamilton. 2018. Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. *British Journal of Psychology* 109, 3 (2018), 395–417.

[20] Thomas D Parsons, Andrea Gaggioli, and Giuseppe Riva. 2017. Virtual reality for research in social neuroscience. *Brain sciences* 7, 4 (2017), 42.

[21] Sandra Poeschl and Nicola Doering. 2015. Measuring co-presence and social presence in virtual environments–psychometric construction of a german scale for a fear of public speaking scenario. *Annual Review of Cybertherapy and Telemedicine 2015* 219 (2015), 58–63.

[22] Nairán Ramírez-Esparza, Adrián García-Sierra, Gloriana Rodríguez-Arauz, Elif G Ikizer, and Maria J Fernández-Gómez. 2019. No laughing matter: Latinas' high quality of conversations relate to behavioral laughter. *PloS one* 14, 4 (2019), e0214117.

[23] Daniel Roth, Constantin Klelnbeck, Tobias Feigl, Christopher Mutschler, and Marc Erich Latoschik. 2018. Beyond Replication: Augmenting Social Behaviors in Multi-User Virtual Realities. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, Institute of Electrical and Electronics Engineers, New York, NY, USA, 215–222.

[24] Sylvia Rothe, Daniel Buschek, and Heinrich Hußmann. 2019. Guidance in cinematic virtual reality-taxonomy, research status and challenges. *Multimodal Technologies and Interaction* 3, 1 (2019), 19.

[25] Sylvia Rothe, Alexander Schmidt, Mario Montagud, Daniel Buschek, and Heinrich Hußmann. 2020. Social viewing in cinematic virtual reality: a design space for social movie applications. *Virtual Reality* 25, 3 (2020), 1–18.

[26] Rufat Rzayev, Sven Mayer, Christian Krauter, and Niels Henze. 2019. Notification in vr: The effect of notification placement, task and environment. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*. Association for Computing Machinery, New York, NY, USA, 199–211.

[27] Gillian M Sandstrom, Vincent Wen-Sheng Tseng, Jean Costa, Fabian Okeke, Tanzeem Choudhury, and Elizabeth W Dunn. 2016. Talking less during social interactions predicts enjoyment: A mobile sensing pilot study. *Plos one* 11, 7 (2016), e0158834.

[28] Martijn J Schuemie, Peter Van Der Straaten, Merel Krijn, and Charles APG Van Der Mast. 2001. Research on presence in virtual reality: A survey. *CyberPsychology & Behavior* 4, 2 (2001), 183–201.

[29] Valentin Schwind. 2018. *Implications of the uncanny valley of avatars and virtual characters for human-computer interaction*. Ph. D. Dissertation. University of Stuttgart.

[30] Valentin Schwind, Pascal Knierim, Nico Haas, and Niels Henze. 2019. Using presence questionnaires in virtual reality. In *Proceedings of the 2019 CHI conference on human factors in computing systems*. Association for Computing Machinery, New York, NY, USA, 1–12.

[31] Jean-Christophe Servotte, Manon Goosse, Suzanne Hetzell Campbell, Nadia Dardenne, Bruno Pilote, Ivan L Simoneau, Michèle Guillaume, Isabelle Bragard, and Alexandre Ghuysen. 2020. Virtual reality experience: immersion, sense of presence, and cybersickness. *Clinical Simulation in Nursing* 38 (2020), 35–43.

[32] William Steptoe, Anthony Steed, Aitor Rovira, and John Rae. 2010. Lie tracking: social presence, truth and deception in avatar-mediated telecommunication. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Association for Computing Machinery, New York, NY, USA, 1039–1048.

[33] 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)*. IEEE, Institute of Electrical and Electronics Engineers, New York, NY, USA, 546–554.

[34] Julie Williamson, Jie Li, Vinoba Vinayagamoorthy, David A. Shamma, and Pablo Cesar. 2021. Proxemics and Social Interactions in an Instrumented Virtual Reality Workshop. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 253, 13 pages. https://doi.org/10.1145/3411764.3445729

[35] Julie R. Williamson, Joseph O'Hagan, John Alexis Guerra-Gomez, John H Williamson, Pablo Cesar, and David A. Shamma. 2022. Digital Proxemics: Designing Social and Collaborative Interaction in Virtual Environments. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 423, 12 pages. https://doi.org/10.1145/3491102.3517594

[36] Jacob O. Wobbrock, Leah Findlater, Darren Gergle, and James J. Higgins. 2011. The Aligned Rank Transform for Nonparametric Factorial Analyses Using Only Anova Procedures. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI '11)*. Association for Computing Machinery, New York, NY, USA, 143–146. https://doi.org/10.1145/1978942.1978963

[37] Amal Yassien, Passant ElAgroudy, Elhassan Makled, and Slim Abdennadher. 2020. A Design Space for Social Presence in VR. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. Association for Computing Machinery, New York, NY, USA, Article 8, 12 pages. https://doi.org/10.1145/3419249.3420112

[38] Amal Yassien, ElHassan B. Makled, Passant Elagroudy, Nouran Sadek, and Slim Abdennadher. 2021. Give-Me-A-Hand: The Effect of Partner's Gender on Collaboration Quality in Virtual Reality. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI EA '21)*. Association for Computing Machinery, New York, NY, USA, Article 392, 6 pages. https://doi.org/10.1145/3411763.3451601

[39] Amal Yassien, Mohamed Ahmed Soliman, and Slim Abdennadher. 2022. QuarantivityVR: Supporting Self-Embodiment for Non-HMD Users in Asymmetric Social VR Games. *i-com* 21, 1 (2022), 55–70. https://doi.org/10.1515/icom-2022-0005

[40] Qimeng Zhang, Ji-Su Ban, Mingyu Kim, Hae Won Byun, and Chang-Hun Kim. 2021. Low-Asymmetry Interface for Multiuser VR Experiences with Both HMD and Non-HMD Users. *Sensors* 21, 2 (2021), 397.