Digital Proxemics as Measures of Social Interaction in Hybrid XR

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(a) Dyads of participants interact in XR while co-located.

(b) Co-located participants interact with a remote participant.

(c) All participants experience a shared virtual environment.

Figure 1: Overview of the experimental setups: co-located XR (all participants in the same room), hybrid XR (co-located participants interacting with a remote partner), and fully shared virtual environment.

Abstract

Hybrid meetings are the new reality, yet they lack the richness of face-to-face interaction. In shared spaces, virtual or physical, interaction relies on more than words: proximity, non-verbal cues, and subtle movements all shape communication. Proximity captures how close we stand, where we face, and how we move around others. This paper investigates how proxemics in dyad and triad conversations translate across physical and virtual contexts. We conducted a study with 24 participants in four groups, completing social tasks under four conditions: face-to-face, co-located XR, remote XR, and hybrid XR. Our instrumentation of physical and virtual environments enables direct comparison. The work contributes a rich open dataset of 2.3 million rows across 32 columns, supporting comparative and replicable analysis. This is the first study to compare proxemics across face-to-face, co-located XR, remote XR, and hybrid XR, offering a foundation for understanding how social space translates across contexts.

CCS Concepts

• **Human-centered computing → Social network analysis**; **Virtual reality**; **User studies**.

Keywords

Social XR, Social Signal Processing

1 Introduction

Why are hybrid meetings still so hard? Despite the development of equal participation practices and social norms, they often end in frustration. The familiar hybrid format, which combines co-location with video-conferencing, creates unequal opportunities for contribution, blocks social cues, and disrupts the flow due to latency and communication breakdowns. Key social signals, such as proximity [20], orientation, and attention [25], are readily available face-to-face but are limited or unavailable remotely [53]. While remote or co-located interactions are experienced uniformly between participants, hybrid interactions can create unequal experiences. eXtended-Reality (XR) has the potential to create more uniform experiences between co-located and remote participants by providing everyone with the same affordances to perceive and perform social signals, and access to the same spaces and interactive capabilities. By *XR*, we refer to the full range of immersive experiences across the Reality-Virtuality Continuum [32].

Prior research shows that proxemic behaviours, how people use space in relation to one another, play a key role in face-to-face

communication [20]. Studies have demonstrated that proxemic behaviours are also important in virtual environments, for example, in maintaining personal space [3, 57], interacting with virtual agents [30], and using proxemic zones within large [58] and small groups [59, 60]. Proxemic behaviours in virtual environments have also been compared to face-to-face interactions [28], but key gaps remain in how we understand proxemics in hybrid XR settings. Additionally, prior work has explored how dyads or triads interact [33], but not how these highly cohesive small group interactions unfold when part of a larger group and a busier shared virtual environment. More fine-grained analysis of proxemics in dyads and triads across face-to-face and XR conditions is needed to better understand how these interactions translate into immersive environments.

In this short paper, we explore how proxemic behaviours in dyads and triads translate across face-to-face (shared physical space), co-located XR (shared physical space, shared virtual space), remote XR (distributed physical space, shared virtual space), and hybrid XR (mix of shared and distributed physical space, shared virtual space). We conducted a controlled study (N=24) of dyadic and triadic interactions across face-to-face, co-located XR, remote XR and hybrid XR conditions. Participants engaged in structured social tasks while proxemic and conversational behaviours were captured in both physical and virtual spaces, as shown in Figure 1. The resulting dataset, consisting of 22 million rows of raw data, provides a new baseline for understanding proxemic cues in dyad and triad social interactions across realities. This paper makes the following contributions:

- A novel dataset comparing dyads and triads interacting across face-to-face, co-located XR, remote XR and hybrid XR conditions, with rich opportunities for secondary analysis.
- Proxemic analysis of dyad and triad interactions across co-located XR, hybrid XR, and remote XR compared with a face to face baseline demonstrating stability of proxemics across these conditions.

2 Related Work

2.1 Proxemics in Physical Spaces

Proxemics, introduced by Hall [20], examines how people use interpersonal distance in social interaction, identifying four zones: intimate (0–0.46m), personal (0.46–1.2m), social (1.2–3.7m), and public (3.7–7.6m). These zones, shaped by multiple senses from micro-expressions to auditory clarity and touch, regulate comfort and engagement [2]. Hall's work, together with Kendon's studies of synchrony [23] and F-formations [24], provides a framework for analysing interactional quality. Synchrony highlights how people coordinate movement for focus, turn-taking, and engagement, while F-formations describe how bodies align to create shared spaces, especially critical in triads, where balance and equal access must be negotiated.

Goffman extends proxemic theory by examining how attention and participation are organized in co-present encounters, distinguishing between unfocused (casual co-presence) and focused (goal-oriented) interactions shaped by implicit and explicit boundaries

[16]. Whyte situates proxemics in urban design, showing how factors such as seating, sun, wind, and noise influence gathering patterns, with effective capacity often differing from physical capacity [56].

At its core, personal space can be understood as a flexible protective zone maintained around oneself in real-life situations, shaping how people navigate social environments [5]. In triadic encounters, these spatial arrangements become especially salient, as participants intuitively adjust positions to maintain balance and mutual engagement [24].

Our work builds on proxemic ethnography, which shows how non-verbal spatial cues shape comfort, intent, and perceptions of closeness, often outweighing verbal content in signalling attitudes and group dynamics [2, 20]. In virtual environments, spatial layout provides a powerful yet underutilised communication channel. However, many cues, such as scent, rich haptics, and natural audio, are absent or altered [49]. At the same time, VR enables deliberate manipulation of proxemic signals, offering both opportunities and risks. How these cues function in hybrid contexts, where co-located and remote participants interact together, remains an open question that motivates our study.

2.2 Proxemics in Social XR

Digital proxemics [28, 60] is a distinct research area concerned with how social signals and interpersonal distance translate into virtual environments. Early work highlighted the role of embodiment and avatar affordances in structuring social interaction, showing that even limited cues for posture, gesture, or orientation can support turn-taking and shared focus [4, 6, 19].

Research on proxemics in XR has primarily examined whether avatar-to-avatar interaction replicates the physiological and behavioural responses observed in face-to-face encounters [1]. Early studies confirmed that virtual spaces can elicit real-world proxemic reactions. For example, Wilcox et al. demonstrated that life-sized stereoscopic images of people presented at 0.5 m caused marked discomfort and physiological arousal equivalent to that induced by a live human approaching [57]. Similarly, experiments employing skin conductance responses (SCRs) have shown heightened arousal when virtual characters violated personal space boundaries [30]. Follow-up studies using stereoscopic projection and head-mounted displays further demonstrated that proxemic violations in XR environments elicit avoidance behaviours and discomfort [57]. Together, these results demonstrate that proxemics in XR are not merely symbolic but embodied: "virtual close talkers" are perceived as aversive in much the same way as real ones.

Immersive environments also afford unique opportunities to investigate proxemics, since agents can be designed to behave in ways that deviate from human norms. Building on this foundation, Nassiri et al. [36] found that personal space is preserved in collaborative virtual environments (CVEs), with users maintaining real-world interpersonal distances when interacting with others. Importantly, subsequent research has shown differences between co-located and remote participants: co-located users often report stronger co-presence and fewer interpersonal collisions than their distributed counterparts [39]. Co-presence, defined as the subject sense of "being there together" in a shared environment, remains

central for structuring communication even when participants are represented by minimalistic avatars. Extending this perspective, Grønbæk et al. [17] emphasise that proxemics in ubicomp and XR contexts must also account for spatial transitions across hybrid environments, highlighting asymmetric participation when some users are immersed and others are not.

This recognition has informed the design of XR systems that regulate interpersonal boundaries. Mechanisms such as dynamic enforcement of personal space zones have been proposed to constrain how avatars or objects may enter these areas [40]. More recent analyses highlight how proxemics in immersive environments shape social norms and protect users from harassment or unwanted contact [31]. Beyond safety, proxemics in XR raise broader design and ethical challenges, including the limits of current affordances, the problem of misinterpretation, and the ethics of "immoral behaviour" in virtual spaces [44]. Recent surveys of social XR research also highlight proxemics as central to the challenges of embodiment, interaction techniques, and social cue representation [62].

2.3 Hybrid Interactions

Hybrid interactions are becoming increasingly common as collaborative and social environments expand to include both co-located and remote participants. A compelling implementation of hybrid communication is found in eXtended-Reality (XR), where users are represented by avatars and can leverage spatial positioning and non-verbal behaviours in shared environments [14]. Research in hybrid collaborative and social contexts has demonstrated that while XR can support task completion, co-located multiplayer VR often introduces challenges [39].

In particular, the occlusion of the body by head-mounted displays (HMDs) increases interpersonal collision anxiety, leading participants to maintain greater distances from teammates and consciously avoid physical contact [51]. Social XR further faces the problem of spatial heterogeneity: users operate in physically distinct environments that must be reconciled to create coherent shared experiences [61]. One proposed solution is the use of digital twins, which provide participants with accurate virtual representations of their physical spaces, enabling controlled comparisons between physical and virtual conditions [15]. Yet, this area of proxemic study in hybrid contexts remains under-investigated, and there exist very few [28] extensive datasets directly comparing physical and virtual human behaviour.

Prior work has shown that rather than concealing the limitations of social XR, making these constraints visible can actually enhance collaboration by allowing users to better understand and manage system characteristics [13]. For example, the deliberate placement of static and interactive objects within virtual rooms can drive proxemic engagement, fostering comfort in sensitive conversations, while even minor spatial modifications can shift group dynamics and power relations [50].

A persistent challenge in XR collaboration is that physically co-present participants often maintain significantly larger interpersonal distances and report greater fear of collision than remote participants sharing the same virtual environment [51]. Such behaviours can undermine communication and cooperation, highlighting that hybrid XR introduces distinct proxemic dynamics
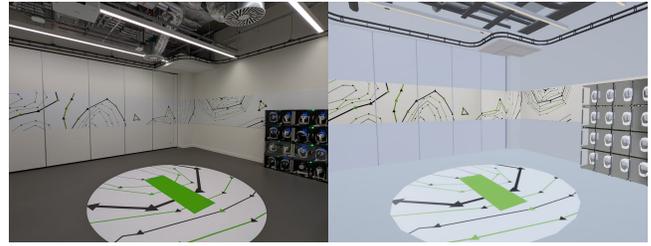

Figure 2: The physical lab (left) and its digital twin (right) offered matched environments for the face-to-face and XR conditions. The space was a square, purpose-built XR lab with minimal furniture and obstructions, allowing participants to move freely.

rather than simply replicating face-to-face interaction. These dynamics are further shaped by users' heightened spatial awareness and the current fidelity of avatar representations.

3 User Study

This short paper investigates how proxemics in dyad and triad conversations translate across physical and virtual contexts. For a direct comparison of proxemic behaviour across realities, we designed a controlled lab study where groups of six participants completed dyadic and triadic interactions in face-to-face, co-located XR, hybrid XR, and remote XR conditions. This research explores how proxemics in small groups translate across these realities in two research questions:

RQ1: Do triads exhibit the same proxemic behaviours when experiencing XR while co-located, hybrid, and remote compared to face-to-face?

RQ2: Do dyads exhibit the same proxemic behaviours when experiencing XR while co-located, hybrid, and remote compared to face-to-face?

3.1 Experimental Design and Setup

The study took place in an XR lab composed of three identical 6.4m x 6.4m cubes and the digital twin of a single cube, as shown in Figure 2. We investigated four experimental conditions: face-to-face, co-located XR, remote XR, and hybrid XR in a counterbalanced within-subjects study, as shown in Figure 4. Conditions were counterbalanced using a latin square, as described in Appendix B.

In the face-to-face condition, all participants interacted within one physical cube, serving as a baseline. In the co-located XR condition, all six participants interacted within one physical cube while appearing together in a single virtual cube. Audio for the face-to-face and co-located XR conditions was within a single room and thus no networking or headphones were used. In the remote and hybrid XR conditions, participants were split across the three cubes in pairs, appearing together in a single virtual cube. Audio for the remote and hybrid XR conditions was networked using voice over IP in Ubiq [47], and all participants wore noise cancelling headphones to block out co-located sounds. Table 4, shows each condition and the distribution of participants across physical and virtual spaces.

Figure 3: Participant view of the virtual room during triad task.

The remote and hybrid configurations allowed for interactions between dyads that were remote (pairs physically in different cubes, virtually in a single cube) and hybrid (pairs physically in a single cube, virtually in a single cube). Note that the hybrid condition for dyads is highly similar to the co-located condition, although other participants interacting simultaneously were not co-located in the hybrid condition. For triads, this configuration allowed for triads that were remote (each participant in a different physical cube, virtually in a single cube) and hybrid (two participants in the same physical cube, one participant in a different physical cube, virtually in a single cube). Figure 3 shows the participant perspective when interacting in the triad.

In the XR conditions, the physical cubes, the virtual cube, and participant positions within each cube were aligned to maintain 1:1 spatial alignment between physical and virtual spaces. Participant movement was through locomotion only in all conditions to maintain this 1:1 alignment between their physical and virtual environments. In the XR conditions, participants were embodied using partial-body Ready Player Me avatars [1]. Before beginning the study, each participant customised their avatar using the Ready Player Me web portal.

Face-to-face participants wore Meta Project Aria devices[2], shown in Figure 5 (left), recording position, orientation, and vocalisation. All devices were time-synchronized, and raw data was processed using Meta's Project Aria Machine Perception Services (MPS). In the XR conditions, participants wore Meta Quest Pro headsets with hand-tracking, shown in Figure 5 (right). Room alignment and avatar positions were networked using Ubiq [47]. Ubiq is an open source networking library that can be used to create XR mediated environments for interoperable devices and platforms with support for logging and data analytics.

3.2 Experimental Tasks

The tasks were designed to facilitate conversations in dyads and triads between strangers as detailed below. The participants were grouped into three dyads or two triads for the experimental tasks, and groups completed these tasks simultaneously.

3.2.1 Dyads: Introduction in Pairs with a Handshake. Participants were instructed to introduce themselves for two minutes, beginning

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[1]https://vr.readyplayer.me
[2]https://www.projectaria.com/research-kit/

Figure 4: Physical and virtual configurations of participants during each condition. Each black outlined square represents a room, and participant groupings are represented as matching colours. The configurations and counterbalancing are described in Appendix B.

Figure 5: Meta Project Aria glasses (left), Meta Quest Pro Head Mounted Display (right).

with a handshake. In face-to-face this was a physical handshake; in XR, participants used either a physical or virtual handshake depending on co-location. The handshake is a key "close salutation" [25], requiring enough closeness for potential physical contact and movement coordination.

3.2.2 Triads: Worst Meal Task. Participants were assigned into groups and instructed to select their least favourite ingredient, and together the group designed the most unappealing meal possible. The "Worst Meal" task, originally designed by Chovil [7] and adapted by Tschachter [52] and Falk [12], was selected to elicit a dynamic collaborative conversation, that supports participation from each group member promoting co-ordinated turn taking and shared attention.

3.3 Participants and Recruitment

Twenty-four participants (four groups of six) were recruited from the local population using a recruitment agency and had no prior knowledge of one another. Participants who required glasses to read were excluded as glasses are incompatible with the hardware used in this study. Participants ranged in age from 18 to 48, with an average age of 31.8. 35% of the participants were female. 65% of the participants reported they had never used virtual reality, 30% reported they had only rarely used virtual reality, and 4% reported
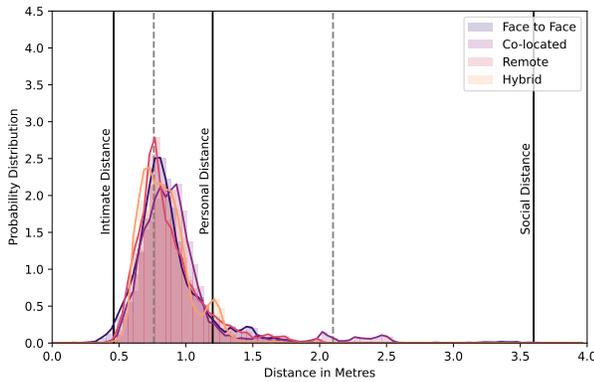
Figure 6: Proxemic distances between triad members during the "Worst Meal" task (30 fps), calculated as pairwise Euclidean distances.

Condition	p	DoF	ϕ_c
Co-located-XR – Remote-XR	<.01	5	0.165
Co-located-XR – Hybrid-XR	<.01	5	0.156
F2F – Co-located-XR	<.01	5	0.140
F2F – Hybrid-XR	<.01	5	0.110
F2F – Remote-XR	<.01	5	0.102
Remote-XR – Hybrid-XR	<.01	5	0.059

Table 1: Results of the Chi-squared test of independence of variables in a contingency table comparing proxemic distances between triads in the Face-to-Face, Co-located, Remote and Hybrid conditions during the *Worst Meal* task. Effect sizes are determined as stated by Shea [43] and all show very small effect size.

they used virtual reality often. These demographics do not include one participant who opted not to provide demographic data.

4 Results

Data was collected from the Meta Quest Pro headsets (XR) and Project Aria Devices (face-to-face). The raw dataset includes 22.3 million lines of positional and rotational data, with 5.3 million lines collected from the XR conditions and 17 million lines from the face-to-face condition. The data from each device was normalised by resampling to 30 FPS, producing 2.3 million rows with 32 columns, described in Appendix C. The complete dataset and all data manipulation techniques are included in the supplements for this paper[3]. Semi-structured interviews were conducted with each group after completing all experimental conditions. The qualitative results were analysed from focus group transcripts using a three stage coding process and thematic analysis [48]. The transcript includes 79 minutes of discussion with 24 participants in groups of 6. Participant identifiers are shown as the group number (1-4) and participant ID (Blue, Green, Orange, Pink, Red, Violet). The interview protocol is provided in Appendix B.

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[3]The raw data, processed data, and all the code for data manipulations and analysis is available in an anonymised OSF repository for anonymous peer review.

4.1 RQ1: Proxemics in Triads

RQ1 addresses how proxemic behaviour in triads translates across face-to-face, co-located XR, hybrid XR, and remote XR conditions. Figure 6 presents the frequency distribution of proxemic distances between triads during the "Worst Meal" task. Distances were calculated as pairwise Euclidean distances between participants' head positions (x, y, z) and expressed as a probability distribution (y-axis). The curves represent kernel density estimates (KDEs) produced using Matplotlib's histogram and density functions[4]. Black vertical lines indicate proxemic zones (intimate, personal, and social distances), and grey dotted vertical lines indicate the near and far segments of these zones.

Previous works have presented frequency distributions of proxemic distances for different group sizes [8, 60]. We suggest that a Chi-squared test using contingency tables best captures proxemic zones [20] and rich time series tracking data (dataframe described in Appendix C). We created the contingency table by binning our time series pairwise Euclidean distances into six proxemic zones: 0 - 0.46 (intimate zone), 0.46 - 0.76 (close personal zone), 0.76 - 1.2 (far personal zone), 1.2 - 2.1 (close social zone), 2.1 - 3.6 (far social zone) and 3.6 - 7.6 (public zone). This approach preserves the time series data, where comparison of means using tests such as ANOVA or Mann-Whitney U would reduce the time series to means or medians and may not be meaningful for interactions that unfold over time.

Table 1 shows comparisons of proxemic distance frequency distributions between each condition. All comparisons are statistically significant, but given the large scale of our time series data effect size is a better indicator of differences [22, 43]. A very small effect size was observed between all conditions, indicating observable proxemic behaviour in face-to-face contexts is stable whether triads are interacting in co-located XR, hybrid XR, and remote XR. This statistical analysis adds further validity to previous research showing that proxemic behaviour is stable in reality compared to virtuality [28, 37].

The qualitative results highlight some participant concerns about space across the XR conditions, consistent with existing research [28]. In co-located XR, some reported near misses:"I think a couple of people did nearly bump into each other" (3B). Others admitted they "didn't quite trust the distance" (4V). By contrast, face-to-face interaction provided more confidence in spacing: "You don't know how close you are (in XR)... in real life you just know to give them space" (1G). Our hybrid XR and remote XR conditions created scenarios where participants could lose track of who was physically co-located and who was remote. For example, a participant stated that "Mad how you couldn't differentiate between people in the actual room that you're in or not" (1O), and "I actually almost forgot that we weren't all in the exact same room" (3G). Others found this familiar, blurring the line between physical and virtual proximity: "It feels normal, you just have a conversation with somebody next to you, although you're not" (1P). This is precisely the kind of "level playing field" we imagined in the introduction when motivating our use of XR for hybrid group interactions in a digital twin.
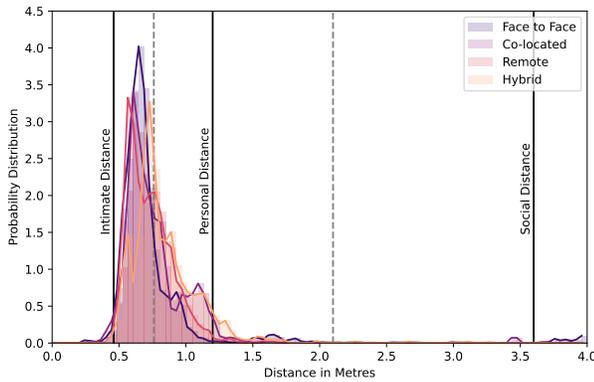
Figure 7: Proxemic distances between dyad members during the "Introductions" task (30 fps), calculated as pairwise Euclidean distances.

Condition	p	DoF	ϕ_c
F2F – Hybrid-XR	<.01	5	0.297
F2F – Remote-XR	<.01	5	0.228
F2F – Co-located-XR	<.01	5	0.210
Remote-XR – Hybrid-XR	<.01	5	0.196
Co-located-XR – Hybrid-XR	<.01	5	0.151
Co-located-XR – Remote-XR	<.01	5	0.097

Table 2: Results of the Chi-squared test of independence of variables in a contingency table comparing proxemic distances between dyads in the Face-to-Face, Co-located, Remote and Hybrid conditions during the *Introductions* task. Highlighted effect sizes show a small effect size.

4.2 RQ2: Proxemics in Dyads

Figure 7 displays the frequency distribution of pairwise Euclidean distances between dyads during the Introductions task using the same conventions as used in Figure 6. Table 2 reports results from Chi-squared tests using the same approach described in Section 4.1

The analysis demonstrates small or very small effect sizes between conditions, which is in line with previous research on the stability of proxemics in reality compared to virtuality[21, 29, 37]. Our experimental design adds the "close salutation" handshake, which required participants to move within arms length proximity to each other and coordinate their movements to achieve a handshake. Qualitative insights add further nuance to how the handshake worked between conditions. In face-to-face, it felt "formal" (3V), while in hybrid XR and remote XR it was more awkward but playful: "You're expecting a tactile response. You don't get one. Just like shaking your hand in the air" (4R). Participants reflected on the challenge of shaking hands not knowing if their partner would be physically co-located or not. One participant stated that "if you're totally VR it might actually be easier because at least you know where the hands are virtually. In co-located VR you're also searching for them physically" (4V). Though participants in the hybrid XR and remote XR conditions could not know whether

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[4]https://matplotlib.org/stable/api/_as_gen/matplotlib.pyplot.hist.html

the handshake would involve physical contact (hybrid XR) or not (remote XR), the maintenance of proxemic zones shown in Figure 7 show that interpersonal distances still remained stable.

5 Discussion

5.1 Are Proxemics Stable Across XR Conditions?

This short paper addresses a key gap in the space of stability of proxemic social signals in XR when participants experience a hybrid mix of remote and co-located conversational partners. Previous research has addressed proxemics in fully remote settings [18, 26, 59] and co-located settings [10, 28], but our dataset closes a key gap with a hybrid mix of co-located and remote participants. We present a statistical analysis with the goal of assessing both proxemic zones and time series data to go beyond the descriptive statistics used in prior works [35, 46]. Using a Chi-squared test with contingency tables binned using proxemic zone boundaries, we confirm that proxemic behaviours are stable comparing face-to-face, co-located XR, hybrid XR, and remote XR.

Our experimental design created interactions where proxemics would be challenged. In the triad interactions, participants could be in a situation where they could not tell who was co-located and who was remote. Triad frequency distributions shown in Figure 6 peak where the close and far personal zones meet, also where the proxemic signal of body heat disappears [20]. In the dyad interactions, participants were instructed to shake hands during their introductions, requiring coordination in the close personal zone shown in Figure 7. Participants mentioned determining hand positions to be more challenging in the XR conditions, an experience perhaps accentuated by uncertainty about whether physical contact would occur. Even when signals like body heat are not always present, proxemics are maintained through other signals in the personal zone like the visual angle taken up by the face and upper body and the arm's length of space surrounding a participant. Even when many social signals are missing, like full body posture, intricate facial expressions, and gait, we found that proxemics for small groups can be stable. This study cannot conclusively answer "Why are hybrid meetings so hard?" though the analysis presented demonstrates that across the reality-virtuality continuum and varying co-location configurations, we continue to utilise our innate ability to communicate using our body and should be consideration to enhance hybrid interactions.

These findings raise broader questions around what happens when immersive asymmetries are introduced (e.g., some in full virtuality, some in a mix of reality/virtuality)? In our study, all XR participants had parity in experience, and proxemic patterns did not significantly diverge from face-to-face. Challenges still remain in comparing our understanding of proxemics in blended asymmetric realities, a "true hybrid" experience. Supporting groups of co-present and telepresent mixed reality interaction to seek understanding of how proxemics unfold when embodiment is heterogeneous, for example, when one participant appears as a flat 2D avatar, and others in full 3D remains an unresolved research area.

A limitation of this work is the focus on small groups in dyads or triads and how these results might apply to larger groups. As groups grow larger, additional conversation partners introduce complexities in attention, turn-taking, and subgroup dynamics that

shape spatial negotiation strategies. Future studies should explicitly consider varying group sizes, as results from dyads and triads may not generalise to larger interactions.

5.2 Secondary Analysis and Future Work

Our dataset contribution extends the landscape of openly available resources on social interaction in XR. While existing repositories such as Rack et al.'s Navigating Datasets [42] and individual user motion datasets [41] provide well-structured schemas for analysing single-user behaviour, they cannot be used for evaluating interpersonal social signals. Our dataset ensures interoperability with established standards [28, 55] while filling a critical gap: multi-user interaction data that mixes co-located, hybrid, and remote interactions in directly comparable physical and virtual environments. Our dataset annotates dyadic and triadic groups for in-depth analysis of small group behaviour.

Our open dataset consists of 22.3 million rows raw data containing positional and rotational head and hand data. The data was resampled to 30 FPS, producing 2.3 million rows with 34 columns. All of the data, including the manipulations from raw data to resampled data, the analysis tools, and code used to generate figures and statistical results are included in the supplements of this paper as open research artefacts.

The analyses in this paper focuses specifically on proxemic distances, but the dataset affords rich opportunities for secondary analysis. Examining balance [38] and coordination in dyads and triads (e.g., synchrony of movement [25], role differentiation [27, 54]). Analysing speech dynamics by aligning spatial data with audio or conversational turn-taking [45], and exploring temporal shifts in head gaze activity during dyadic and triadic tasks as measures of social / interactional synchrony [9, 34, 52]. In making this dataset openly available, we hope to encourage comparative and replicable work that situates proxemic behaviour within broader theories of collaboration and interaction outcomes.

6 Conclusion

This paper explores proxemic behaviours when groups of six participants are organised into dyads and triads while interacting face-to-face, co-located XR, hybrid XR, and remote XR. We conducted a between subjects study where 24 participants in groups of 6 completed conversational tasks in instrumented physical and virtual environments. The resulting dataset includes 2.3 million rows of processed behavioural data downsampled to 30Hz for analysis from a raw corpus of 22.3 million rows. Our quantitative analysis show that proxemic behaviours were stable in XR conditions compared to face-to-face, with our work contributing a new hybrid XR condition to the growing body of work and open datasets in this space. This paper contributes an open dataset and set of analysis tools to enable rich secondary analysis, including annotations about group organisation and activity for detailed analysis of small group behaviour. This paper promotes a data-driven approach to understanding the future of social XR, where models and interventions can build from a growing corpus of interaction in XR datasets to improve how we can be social in immersive environments.

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A   Data Tables

A.1   Proxemic Plots

The histograms presented in Figure 6 and Figure 7 were generated by plotting four time series in 100 bins. For simplification these data table displays the time series in 10 bins.

Figure 6:

Bin Number	Lower Edge	Upper Edge	Face to Face	Co-located-XR	Remote-XR	Hybrid-XR
1	0.0	0.7	0.19	0.14	0.19	0.19
2	0.7	1.4	0.75	0.79	0.76	0.80
3	1.4	2.1	0.05	0.04	0.05	0.01
4	2.1	2.8	0.00	0.03	0.00	0.00
5	2.8	3.5	0.01	0.00	0.00	0.00
6	3.5	4.2	0.00	0.00	0.00	0.00
7	4.2	4.9	0.00	0.00	0.00	0.00
8	4.9	5.6	0.00	0.00	0.00	0.00
9	5.6	6.3	0.00	0.00	0.00	0.00
10	6.3	7.0	0.00	0.00	0.00	0.00

Figure 7:

Bin Number	Lower Edge	Upper Edge	Face to Face	Co-located-XR	Remote-XR	Hybrid-XR
1	0.0	0.7	0.56	0.45	0.46	0.24
2	0.7	1.4	0.38	0.53	0.53	0.73
3	1.4	2.1	0.03	0.01	0.01	0.02
4	2.1	2.8	0.01	0.00	0.00	0.00
5	2.8	3.5	0.00	0.01	0.00	0.00
6	3.5	4.2	0.02	0.00	0.00	0.00
7	4.2	4.9	0.00	0.00	0.00	0.00
8	4.9	5.6	0.00	0.00	0.00	0.00
9	5.6	6.3	0.00	0.00	0.00	0.00
10	6.3	7.0	0.00	0.00	0.00	0.00

B   Experiment Protocol

00:00 – 00:05 Welcome and Introductions

- Greet participants.
- Briefly introduce the research team.
- Allow participants to introduce themselves.
- Assign stickers (red, blue, green, violet, orange, pink) and numbers (1–4).

00:05 – 00:10 Participant Consent Form

- Explain purpose, procedure, confidentiality, and voluntary participation.
- Provide and collect signed consent forms with the appropriate colour coding (e.g., red 1 = red sticker person from the first group).
- Character customisation.

00:10 – 00:15 Introduction to the Study

- Explain objectives and tasks.
- Provide 10 minutes to go through the setup and a few minutes to explain the tasks and answer follow-up questions.

See Table 3 for participant allocation and Table 7 for condition assignment.

00:10 – 00:30 Condition 1 Protocol

- Pair up in the following combinations.
- Task 1: Introduce yourselves in pairs (2 minutes). Ensure you shake hands.

See Table 4.

00:30 – 00:50 Condition 2 Protocol

See Table 5.

00:50 – 01:10 Condition 3 Protocol

See Table 6.

01:10 – 01:30 Interview and Closing

- Participants record their assigned colour aloud.
- Interview prompts included:
  - Initial reactions to the three conditions (F2F, VR together, VR in separate rooms).
  - Differences and similarities across conditions.
  - Reflections on introducing themselves and shaking hands in each condition.
  - Perceived success in completing the *Worst Meal* task.
  - Comfort, discomfort, and surprising aspects of the experiences.

Protocol Tables

Participant	Colour	Room
P1	Pink	A
P2	Blue	A
P3	Purple	B
P4	Green	B
P5	Orange	C
P6	Red	C

Table 3: Participant allocation by colour and room.

Task	Groups
Introductions	Pink & Blue
	Purple & Orange
	Green & Red
Worst Meal (Task 1)	Purple, Green, Pink
	Red, Orange, Blue
Worst Meal (If Hybrid)	Purple, Blue, Red
	Green, Orange, Pink

Table 4: Condition 1 task and group allocation.

Task	Groups
Introductions	Pink & Orange
	Purple & Green
	Blue & Red
Worst Meal (Task 2)	Pink, Blue, Purple
	Red, Orange, Green
Worst Meal (If Hybrid)	Purple, Blue, Red
	Green, Orange, Pink

Table 5: Condition 2 task and group allocation.

Task	Groups
Introductions	Pink & Purple
	Blue & Green
	Orange & Red
Worst Meal (Task 3)	Pink, Blue, Red
	Purple, Green, Orange
Worst Meal (If Hybrid)	Purple, Blue, Red
	Green, Orange, Pink

Table 6: Condition 3 task and group allocation.

	Condition 1	Condition 2	Condition 3
Group 1	F2F	CL	HR & HCL
Group 2	HR & HCL	F2F	CL
Group 3	CL	HR & HCL	F2F
Group 4	F2F	HR & HCL	CL

Table 7: Group allocation to experimental conditions.

C Data Schema

The raw data, processed data, and all the code for data manipulations and analysis is available in an anonymised OSF repository for anonymous peer review.

Column Name	Description	Convention
timestamp	Date time	milliseconds
participant_id	A unique identifier	String
position_x	World coordinate, x	X/Y horizontal, Z vertical
position_y	World coordinate, y	
position_z	World coordinate, z	
rotation_x	Rotation quaternion, x	forward, backward, left and right vectors are derived from quaternion
rotation_y	Rotation quaternion, y	forward, backward, left and right vectors are derived from quaternion
rotation_z	Rotation quaternion, z	forward, backward, left and right vectors are derived from quaternion
rotation_w	Rotation quaternion, w	forward, backward, left and right vectors are derived from quaternion
device	Descriptor of the device used for this log	String
trial_id	A unique identifier	String
activity	Description of activity	String
task	Descriptor of task	String
condition	Descriptor of condition	String
participants	List of participants	String
gaze_position_x	World coordinate, x	Unified gaze format
gaze_position_y	World coordinate, y	
gaze_position_z	World coordinate, z	
left_hand_position_x	World coordinate, x	Wrist used as position point
left_hand_position_y	World coordinate, y	
left_hand_position_z	World coordinate, z	
right_hand_position_x	World coordinate, x	
right_hand_position_y	World coordinate, y	
right_hand_position_z	World coordinate, z	
left_hand_direction_x	Vector relative to wrist, x	z faces outward from inner wrist
left_hand_direction_y	Vector relative to wrist, y	
left_hand_direction_z	Vector relative to wrist, z	
right_hand_direction_x	Vector relative to wrist, x	z faces outward from inner wrist
right_hand_direction_y	Vector relative to wrist, y	
right_hand_direction_z	Vector relative to wrist, z	
is_speaking	Utterance during frame	Boolean
is_speaking_tgt	Utterance by target participant	Boolean