Social XR: Designing An Extended Reality Application for Interaction in Long-Distance Relationships

DEZIJIAN ZHOU, Design Lab, Sydney School of Architecture, Design and Planning, The University of Sydney, Australia and Design for Performance and Interaction, The Bartlett School of Architecture, University College London, United Kingdom
YUANYUAN DENG, Design for Performance and Interaction, The Bartlett School of Architecture, University College London, United Kingdom
ANASTASIA GLOBA, Sydney School of Architecture, Design and Planning, The University of Sydney, Australia
RICHARD DAVIES, College of Computing, Birmingham City University, United Kingdom
YONGQUAN HU, University of New South Wales, Australia
RUO-XUAN WU, Design Lab, School of Architecture, Design and Planning, The University of Sydney, Australia
LIYA FU, College of Digital Art and Design, Dalian Neusoft University of Information, China
AARON J QUIGLEY, Science Director and Deputy Director, CSIRO's Data61, Australia

Fig. 1. This study proposes three innovative interactive prototype systems to enhance long-distance relationships: the Non-verbal Information Visualization System, the Spatial Component Layout System, and the Peripersonal Spatial UI System.

With the acceleration of global population mobility and changes in living structures, long-distance social relationships have become increasingly common. However, current digital communication tools may not fully support our social expectations.

Authors' Contact Information: Dezijian Zhou, dzho0167@uni.sydney.edu.au, Design Lab, Sydney School of Architecture, Design and Planning, The University of Sydney, Sydney, NSW, Australia and Design for Performance and Interaction, The Bartlett School of Architecture, University College London, London, England, United Kingdom; Yuanyuan Deng, yuanyuan.deng.22@alumni.ucl.ac.uk, Design for Performance and Interaction, The Bartlett School of Architecture, University College London, London, England, United Kingdom; Anastasia Globa, anastasia.globa@sydney.edu.au, Sydney School of Architecture, Design and Planning, The University of Sydney, Sydney, NSW, Australia; Richard Davies, richard.davies@bcu.ac.uk, College of Computing, Birmingham City University, Birmingham, England, United Kingdom; Yongquan Hu, University of New South Wales, Sydney, NSW, Australia; Ruo-Xuan Wu, russian.wu@sydney.edu.au, Design Lab, School of Architecture, Design and Planning, The University of Sydney, Sydney, NSW, Australia; Liya Fu, fuliya@neusoft.edu.cn, College of Digital Art and Design, Dalian Neusoft University of Information, Dalian, Liaoning, China; Aaron J Quigley, aaron.quigley@data61.csiro.au, Science Director and Deputy Director, CSIRO's Data61, Sydney, NSW, Australia.

This study explores the affordances and limitations of technology that can be used for "long-distance" social interactions. This paper employs a range of research methodologies including literature review, design work analysis, and experimental participatory design methods. With these, this work proposes and introduces a Social XR mobile application, which includes two fundamental systems: (1) non-verbal communication and (2) contextual spatial interaction. The results of this study indicate that non-verbal and spatial interactions can enhance intimacy and companionship in long-distance relationships to a certain extent. However, the system imposes significant mental and effort-related demands on users, with varying experiences among different users. The findings suggest that future designs should consider user guidance tutorials, age-specific design considerations, multi-modal interactions to enhance emotional connections, and adaptations for diverse scenarios. The limitations and directions for future research, in terms of longitudinal research, for example, conclude this paper.

CCS Concepts: • **Human-centered computing** → Mixed / augmented reality.

Additional Key Words and Phrases: Extended Reality, Long-Distance Relationship, Digital Intimacy, Nonverbal Communication, Spatial Interaction

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1 Introduction

1.1 Background

Maintaining meaningful connections in long-distance relationships is a common challenge faced by individuals globally due to geographical separation. Physical separation poses an obstacle in these partnerships, often resulting in sentiments of isolation and emotional detachment. According to recent studies, many individuals living in the United Kingdom and Europe and a notable proportion of those who live in China's first-tier cities, have encountered challenges associated with maintaining long-distance relationships [9, 10]. Moreover, the extended physical distance and the current limitations of online communication methods make the challenges more difficult for couples. According to [31], a study conducted in the United States, revealed that 50% of individuals engaged in long-distance relationships experience feelings of loneliness. Furthermore, 42% of these individuals attribute the failure of their relationships to inefficient communication.

In addition, non-verbal communication significantly influences interpersonal relationships since humans primarily depend on visual and non-verbal cues when engaging in interactions [27]. In long-distance relationships, however, visual interaction is diminished, due to the extended physical distance and limited visual coverage. This can significantly disrupt the quality of social interaction [11]. Although conventional online communication tools provide a means for interaction, they often fail to convey the emotional depth between parties. For example, while video chatting offers long-distance couples an avenue to see each other's facial and bodily expressions, it remains constrained by its inherent limitations, such as limited field of view, a lack of genuine interactive experience and susceptibility to visual distractions. Modern couples progressively gravitate towards more immersive interaction modes [38]. Classical textual, video, and voice interactions may no longer satisfy their thirst for genuine connection. Some users have already ventured into VR Chat, Rec Room, and Spatial platforms, harnessing VR headsets for remote social experiences. However, these experiences focus predominantly on virtual activities, virtual touch, and customization of virtual avatars rather than truly bridging the emotional and non-verbal communication gap between individuals.

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Given this, recent advancements in Extended Reality (XR)—encompassing Virtual Reality (VR), Mixed Reality (MR), and Augmented Reality (AR)—present a promising avenue for improving social interaction in long-distance relationships [38]. Initially, XR was largely confined to professional disciplines or small-scale gaming/social applications. However, with the continuous improvement in technology, such as Apple's Apple Vision Pro, improved immersive digital experiences have become possible, transforming how individuals perceive the world and interact with it[5]. In addition, [22] notes that new development opportunities arise for applying XR technology in various fields as technology advances. This study presented here applies extended reality techniques to the problem of "social bonding" between long-distance couples, a concept we refer to as "Social XR".

1.2 Research Objectives

The primary aim of this study is to explore the opportunities and challenges faced by long-distance couples when using Social Extended Reality to enhance their intimate relationships. This research seeks to accomplish the following main objectives:

(1) By analyzing current remote XR systems, we investigate and explore the technical, psychological, and physiological challenges faced by users in maintaining long-distance relationships during remote social interactions, with a focus on strengthening intimacy, facilitating emotional conveyance, and enhancing social interaction.
(2) Designing and developing an XR prototype system tailored to the needs and characteristics of users in long-distance relationships. The potential features could include immersive communication, emotion recognition systems, and spatial interaction mechanisms to enhance user's remote social experience.
(3) Evaluating how XR systems assist users in long-distance relationships in more effectively expressing emotions and maintaining intimacy by evaluating the usability of the user interface, the quality of emotional connection, and the effectiveness of long-distance communication.
(4) Finally, conduct a summative evaluation of a proposed XR prototype system and introduce directions for future developments and improvements based on the evaluation results.

2 RELATED WORK

Building on prior research, XR dating has been shown to potentially enhance the effectiveness of establishing and maintaining relationships [38]. Concurrently, the growing ubiquity of wearable devices has opened up new avenues for social interaction through perceived physiological responses [21]. Furthermore, recent investigations have highlighted the expressive potential of biological signals [18], introducing an additional dimension to digital interactions. This study also seeks to explore spatial interaction-based products to investigate the design of interactions that transcend geographical boundaries. Consequently, this section will analyze works within the frameworks of "non-verbal communication" and "engaging in shared spatial interaction."

2.1 Nonverbal Communication

Non-verbal communication plays a significant role in fostering intimacy in long-distance relationships. Specifically, non-verbal communication is essential for two individuals to develop a strong emotional bond, increase understanding and empathy, and facilitate more engaging conversations [27]. Using a mobile phone connection, the [30], for instance, allows users to kiss and interact with others anywhere in the world. However, according to Israeli designer [32], modern technology cannot fully simulate the feeling of physical contact between people and cannot satisfy the psychological needs of interpersonal communication. As a result, she conceptualizes intimate relationships in real life in multiple works. I Am With You [32] converts the vibration of the other person's heart rate into the contraction of the surrounding objects. However, this reliance on heartbeat cues alone may limit the system's ability to convey a full range of emotions, potentially leading to misinterpretation and reducing its effectiveness in fostering nuanced emotional connections. Similarly, Sending A Kiss [32] converts the motion of kissing into the vibration of the wings, enhancing the feeling of companionship between the two individuals by permitting individuals to experience this psychological pleasure and fulfillment once more, though its usage context is limited to expressing single gestures rather than facilitating ongoing interactions.

Similarly, the work Pillow Talk by British designer [25] allows users to wear a wristband that detects and transmits their heartbeat, enabling them to hear their loved one's heartbeat in real time through their pillow. While it effectively translates biological signals into auditory feedback to enhance a sense of presence, Pillow Talk is limited by its situational dependency; it is primarily designed for use in bed, restricting its utility across diverse daily contexts. This limitation may reduce its overall impact on long-distance intimacy, as users can only experience this connection within specific settings rather than during a wider range of relational interactions.

While numerous innovations exist, many, such as specialized pillows and kissing machines, have inherent limitations. These devices often rely on specific hardware, which can restrict user mobility and spontaneity, highlighting the need for more convenient and practical solutions. In contrast, non-verbal communication designs utilizing everyday tools, such as *iMessage* on smartwatches and smartphones [1], offer a more streamlined and accessible alternative. The *Significant Otter*, as introduced by [21], takes this a step further. The application adeptly captures the subtle emotions frequently overlooked in traditional messaging, cultivating a more genuine and profound bond between couples. By sharing touch, heart rate, and other biosignals, it not only bridges emotional gaps but compensates for linguistic communication limitations.

2.2 Engaging in Shared Spatial Interaction using Digital Technology

Through spatial communication, long-distance couples can better understand each other's lives, enhance emotional connection, and reduce each other's loneliness by sharing their own lives. For example, the work *inFORM* from the MIT Media Lab, described by [30], bridges the gap between digital information and physical interaction. It allows for physical movement and interaction across space and distance. In addition, [2] is a remote synchronous lamp that can reflect each other's status at home in real time. Specifically, by recognizing the human body after returning home, it can send signals and light up the physical world of each other. This provides instant communication and feedback between couples, enhancing their emotional connection and sense of security. In addition, [17] allows couples to remotely interact with each other in two-dimensional space through timed photography, leaving messages, drawing, adding virtual objects, adding animations, etc., to make users feel like they are present in their partner's physical life.

Although these design works can affect each other's physical world space to a certain extent. However, these works cannot convey detailed information such as text and data, and couples need to buy and install unique equipment and ensure that it is set up and working correctly, which may require some investment and maintenance.

XR has a better track record of enhancing the social life of couples, friends, and family members. One might assume that XR dating will revolutionize how people form romantic and sexual relationships, allowing them to establish and maintain relationships more effectively [13]. At the same time, platforms such as Apple Vision Pro [5], Pico 4 Ultra [3], Meta Quest3 [23], and Google AR Core [8] offer developers and users immersive experiences based on visualization and interaction design, the possibility of seamlessly merging the real world with the digital world. This means that users can share the experience of living in a geographic space. Meanwhile, with the growing popularity of wearable devices, perceived physiological responses provide new opportunities for social interaction [21]. Moreover, recent research has demonstrated the expression potential of biological signals [18], which can add another dimension to digital interactions.

2.3 Literature Reviews

To better frame this research question concerning the use of Social XR in intimate relationships, we will base this research on conceptual frameworks that investigate the dimensions of intimacy and personal relationships. Drawing from Miller's seminal work, *Intimate Relationships* [24], this book offers a systematic, comprehensive, and scientifically grounded perspective on love, intimacy, and their various dimensions. These insights serve as a vital theoretical foundation for the design and application of Social XR, circumventing the pitfalls of unscientific stereotypes in the design process. For instance, the challenges of long-distance relationships are not merely rooted in physical separation and lack of constraints but, more crucially, in the disparities between expectations and reality upon reunification.

Table 1. Intimate relationships and their different dimensions.

The Spectrum of Love	**Intimate**	**Desire**	**Loyalty**
Loveless	Minimal	Minimal	Minimal
Fondness	Intense	Minimal	Minimal
Infatuation	Minimal	Intense	Minimal
Hollow Love	Minimal	Minimal	Intense
Romantic Love	Intense	Intense	Minimal
Affectionate Love	Intense	Minimal	Intense
Foolish Love	Minimal	Intense	Intense
Perfect Love	Intense	Intense	Intense

Moreover, the diverse ways in which individuals express and perceive love, as outlined by Chapman and Campbell in *The 5 Love Languages* [6], should be taken into account in the design process. This literary work explores the various manifestations and emotional experiences associated with expressing love across individuals. In social extended reality (XR), these ideas offer valuable insights for guiding design and interaction strategies. This means that social XR applications need to have a variety of expressions. For example, haptic feedback in an XR environment may be especially important for those whose primary love language is "physical touch." And for people whose "receiving gifts" is their primary love language, visual cues, and spatial object messages might be paramount.

2.4 Background / Summary of Related Work

According to previous research, long-distance non-verbal interaction may enable people to establish and maintain relationships more effectively [13]. However, some products that utilize non-verbal communication are limited in conveying emotions and specific information such as text and data. Similarly, Park and Suk [26] argue that when users attempt to express their emotions remotely through XR, the outcome may result in misunderstandings and confusion.

Furthermore, current digital systems for long-distance spatial communication predominantly depend on two-dimensional visual, auditory, tactile, or other non-verbal interactions to transmit information. Although certain platforms and devices can partially mitigate the constraints of physical separation, they fall short of truly immersing users in each other's life contexts. This shortcoming leads to a deficiency in emotional resonance and authentic experiential engagement. Moreover, these systems normally necessitate the acquisition of specialized equipment or the allocation of dedicated spaces for user training and maintenance, thereby constraining their practical applicability and hindering widespread adoption.

Through the analysis of relevant works and the frameworks of different dimensions of love and the "Five Love Languages," our study should address the limitations of emotional conveyance, weak information acquisition, and monotonous communication in existing long-distance social interactions. Additionally, it is essential to consider reducing reliance on specialized equipment and minimizing the associated learning and maintenance costs.

3 Research Methodology

To expedite the validation of research question outcomes, this study adopts the "Research through Speculative Design Method" as its overarching research strategy. Throughout the research process, a user-centered design approach within XR is utilized, facilitating the iterative refinement of design concepts and artifacts through the use of specially developed prototyping tools [12, 37].

This design methodology unfolds across three primary stages: the foundational stage, the ideation and iteration stage, and the reflection stage. Initially, a literature review and analysis of related works is conducted to identify gaps and needs in current research, leading to the development of conceptual designs. In the prototype design, we created an immersive space and a non-verbal communication integration system. We also critically examine and envision how this design approach could assist long-distance couples in maintaining long-term intimate relationships in remote settings, as well as the challenges they might encounter. During the ideation and iteration phase, our team conducts user experience testing of the prototype through internal co-creation workshops. The analysis of results and evaluation feedback was used to guide future iterative design and research.

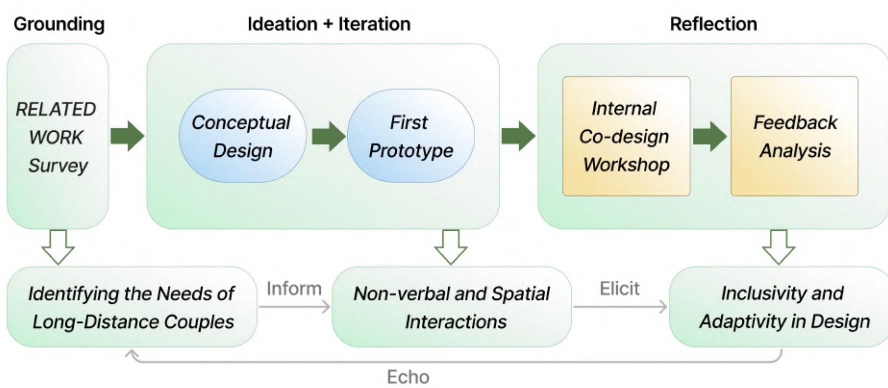

Fig. 2. Research through Speculative Design Method.

4 PROTOTYPING / DESIGN PROCESS

In terms of design objectives, we primarily consider how to utilize non-verbal information to help users in long-distance relationships achieve spatial interaction beyond geographical boundaries. The implementation of this design scheme needs to be based on everyday tools commonly used by users, such as mobile phones and watches, to reduce reliance on specific devices and increase the convenience and universality of the scheme. At the same time, this scheme can consider using non-verbal information by converting it into other sensory forms to enhance the sense of companionship and promote effective communication.

The design underwent three stages. In the first phase, we focused on how biological signals, such as heart rate, could be represented in a shared space. We used Xcode, Unity, and Reality Composer Pro for prototype development. The heart rate from the iWatch was monitored via iOS Health Kit and the signal was connected to an iPhone. During this process, the heart rate was transformed into sensory information such as phone vibrations, 3D emojis representing four different emotions, color-changing layers in the physical space, and color-changing smart lighting. Users can perceive these non-verbal cues through the iPhone and iWatch.

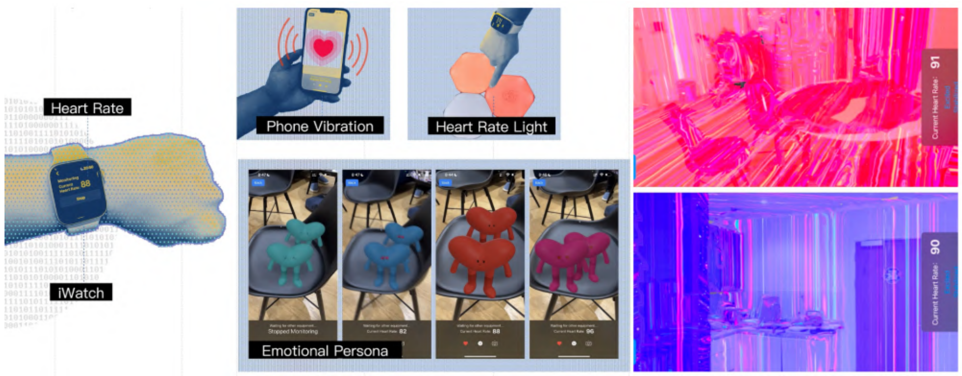

Fig. 3. The Conversion of Biological Signals in XR.

The second phase of our design focuses on facilitating spatial interaction across geographical boundaries for couples in long-distance relationships, whom we refer to as User A and User B. This phase aims to enhance spatial connectivity and space-based interaction. Initially, User A utilizes an iPhone to capture a digital model of her daily living space, which is then uploaded to a cloud server. User B can subsequently access this digital model through an iPhone, where he can place virtual objects at specific coordinates of this digital model. These virtual objects are then perceptible to User A in her real-world environment through MR glasses, thereby enabling spatial interaction beyond geographical boundaries.

Users can utilize mixed reality technology to present elements and events from their surroundings to a distant partner in a more multidimensional and immersive manner. This approach allows the partner to experience the user's environment and experiences more authentically, thereby fostering a deeper sense of presence and companionship and strengthening emotional connections.

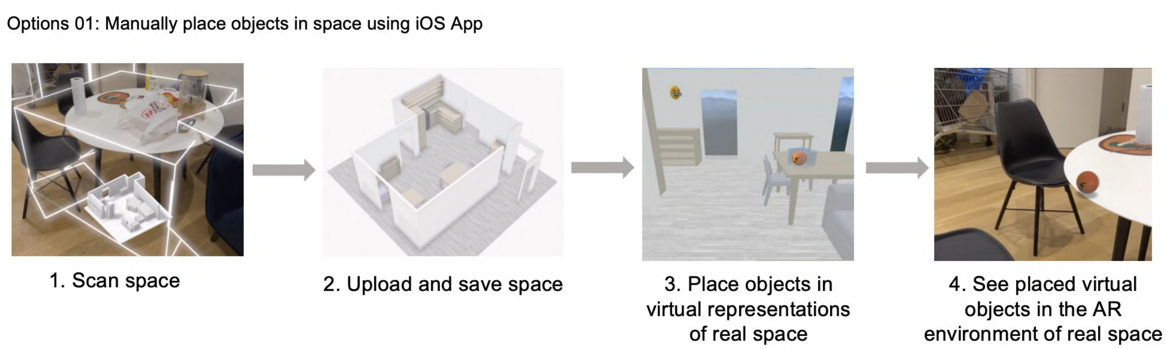

Fig. 4. Spatial Interaction Flowchart.

Fig. 5. Using Social XR for Spatial Interaction During Chinese New Year Celebrations.

In the third phase, we considered how to manage shared data conveniently and efficiently to promote effective communication despite the constraints of long distance. We proposed the concept of using slots within a spatial component layout system to manage and place objects. Additionally, the shared data is categorized into four parts: personal data, objective goals, interactive objects, and social information. Corresponding slots are reserved in the space according to these data categories, allowing for more efficient placement of items. When users share data, virtual objects are automatically placed in the appropriate slots. Furthermore, walls can serve as carriers for digital screens to display various types of information. These digital screens are positioned within work and living spaces based on people's daily activities.

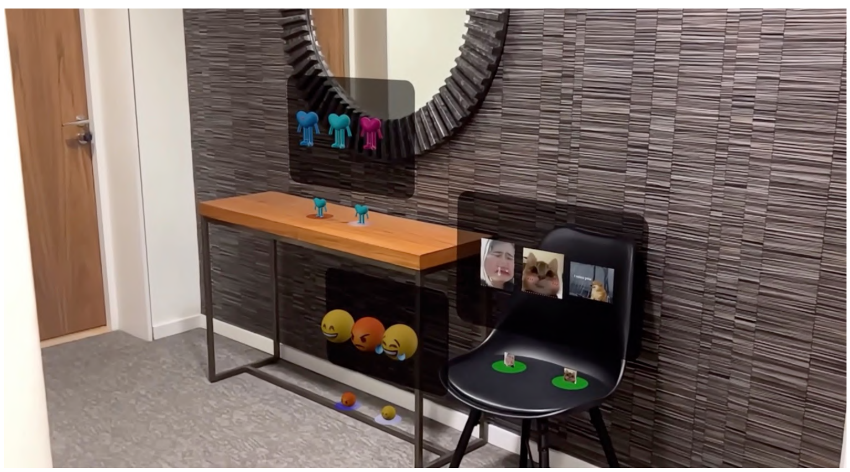

Fig. 6. Slot in a Spatial Component Layout System.

5 EVALUATION

The potential of non-verbal communication and spatial interaction in Extended Reality (XR) to enhance long-distance relationships was explored through internal testing. First, this study observed the interactions between internal users and experts with the prototype, the challenges encountered during actual use, and the feedback on interface layout and interactive functionalities. Feedback was then gathered through semi-structured interviews to gain their perspectives. The feedback was crucial in improving the design prototypes and prioritizing user needs. We conducted an experiment focused on addressing the following research questions.

1: How does non-verbal communication in XR systems enhance emotional transmission and intimacy in long-distance relationships?

2: How do spatial interactions in XR systems overcome physical distance to enhance the sense of presence and companionship in long-distance relationships?

5.1 Participants

The primary participants in this study included the co-supervising teachers and students. Their professional backgrounds included psychologists, human-computer interaction designers, architects, XR experts, and UX designers. Seven members of the research team participated in the study (R1-R7), five of whom had experience in long-distance relationships (4 identified as male, 3 as female, with an average age of 36.86 years, SD = 17.83). The participants' ages ranged from youth to middle-aged and elderly. They served as test users, simulating the behavior of the target population.

5.2 Experimental Procedure and Tasks

After obtaining the necessary consent, internal participants could explore, utilize, and critically evaluate various product features. They interacted with two core tasks and subsequently provided their feedback and suggestions.

•Task 1: Emotion Expression: We explored how biological signals like heart rate can enhance communication and companionship. Users attempted to express certain emotions (e.g., excited, calm, and down) through an Apple Watch. The smartwatch monitors the heart rate and translates it into the smartphone's vibration speed, color, and intelligent lighting frequency. This task helped test and understand the usability and accuracy of the emotion transmission function.

•Task 2: Shared Space: Users captured their living space and shared it with others through an app. They attempted to add preset virtual objects to the shared space. This task aimed to understand shared space features' ease of use and utility. It simulated daily communication scenarios, such as one person at the workplace while the other at home. This task helped us determine whether the product could meet user needs in actual usage scenarios and identify potential issues or challenges.

6 RESULTS

Critical areas for improvement were identified after systematically collecting, filtering, and analyzing internal user feedback and combining it with the users' expertise. This study first used Figure 7, the NASA Task Load Index (NASA-TLX) [14], to assess participants' workload during the task, including mental demand, physical demand, temporal demand, effort, and frustration. Meanwhile, Figure 8 presents the results of the Likert scale assessment [19], showing participants' subjective experiences with the XR system, covering dimensions such as the accuracy of non-verbal communication, enhancement of intimacy, increased sense of companionship, and future usage frequency. Finally, Table 2 highlights the critical user comments that emphasized the challenges of using the current prototype and provided suggestions for future iterations, particularly those offering feedback enriched with specific scenarios, emotional descriptions, and in-depth user experiences.

The combination of Figure 7 and Table 2 indicates that the current system imposes a significant mental and effort load on most participants, with varying experiences among different users when facing the task. Therefore, future designs should consider incorporating user guidance tutorials, streamlined spatial information input, age-specific design considerations, multimodal interactions to enhance emotional connections, and design adaptations for diverse scenarios, indicating that existing designs require further optimization to meet the needs of different user groups and usage scenarios.

Additionally, as initially reflected in Figure 8, the feedback received demonstrated the feasibility of enhancing intimacy in long-distance relationships through spatial interaction and non-verbal communication. It also

Table 2. Key feedback on the challenges of using the current prototypes and suggestions for future iterations.

Researcher ID	Feedback	Remarks
R2	Melding non-verbal cues with video chats would make the chats feel more 'present' and immersive.	Similar to R3, R5, R7
R4	When using this technology at home, I sometimes find the interface too complicated. For someone like me, an older user, could there be a simpler mode?	Unique feedback
R5	In long-distance interactions, I often feel like there's a lack of real emotional connection. The vibration feedback helps a bit, but it doesn't really convey the nuances of how I'm feeling.	Similar to R2, R3, R4, R6, R7
R6	I would prefer to see designs that better adapt to a variety of environments, such as at home or in outdoor spaces.	Similar to R2, R3, R5, R7
R7	When I first used SocialXR, I was kinda lost. It'd be great to have clear community guidelines or tutorials to help newcomers like me get the hang of things faster.	Similar to R4, R5, R6

emphasized the importance of spatial interaction and the transformation of biological signals in strengthening intimacy. This suggests that users place great importance on these features in maintaining and interacting emotionally over long distances.

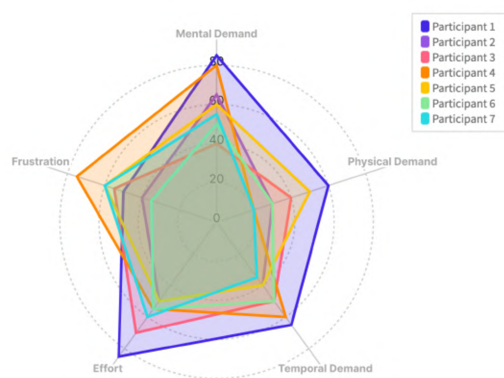

Fig. 7. NASA-TLX Workload Assessment: Participant Ratings Across Key Dimensions.

7 DISCUSSION

7.1 LIMITATIONS

While this study effectively highlights the potential benefits of XR technology in facilitating non-verbal communication and spatial interaction for long-distance couples, several limitations should be acknowledged. Firstly,

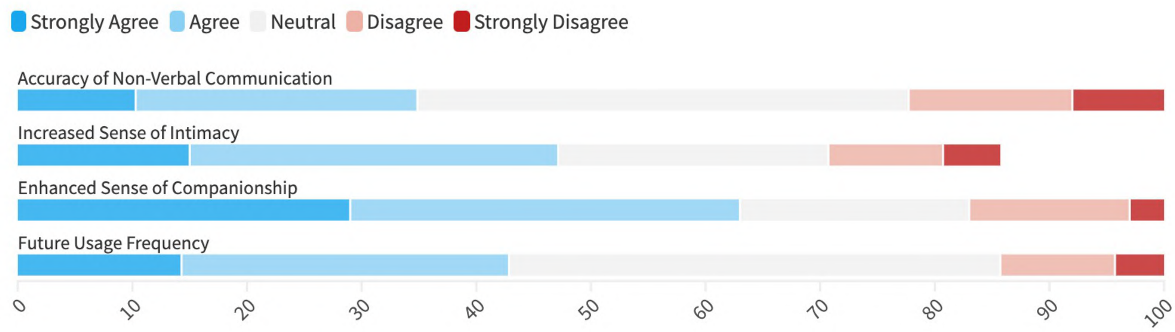

Fig. 8. Survey responses on the effectiveness of the Social XR system, focusing on key performance indicators and addressing core research questions.

the participants were limited to internal testing within the research team, which may result in a lack of representativeness in the sample and a potential bias, as these participants are more familiar with XR technology than the general population. Additionally, the tests were primarily limited to laboratory experiments, and accurate tests were not conducted for long periods in the real world due to time and cost constraints. This shortcoming prevents a full simulation of users' actual reactions in real-life situations, potentially impacting the study's validity. The fact that the research did not consider age groups among long-distance couples, whose technology usage habits, conversational styles, and emotional communication demands may differ, could also be cited as a limitation.

Though the study might have weaknesses, it still provides insightful findings. It brings a fresh perspective to improve relationships between long-distance couples through interaction, addresses current research gaps, and outlines possible challenges that may arise during the design and development phase, forming a preliminary platform for future systems based on non-verbal communication and spatial interaction.

7.2 FUTURE RESEARCH

One of the key limitations of this study is that social XR design experiments were conducted in a controlled/laboratory environment. To overcome this limitation future research can be extended to consider a variety of settings, contexts and scenarios. Since remote interaction is a part of everyday life, designing environments suitable for diverse user groups and user preferences is necessary[28]. Differentiated design approaches should be incorporated in future studies to better align with the expectations and needs of various user groups. Interaction modes, interfaces, and systems can be simplified and made customisable to reduce cognitive load and accommodate potential physical limitations, such as reduced dexterity or vision impairments.

However, single-modal visual or auditory long-distance interactions may not fully meet the needs of emotional transmission. Although converting biological signals into long-distance tactile non-verbal interaction via smartphone vibrations can partially compensate for this, such methods lack precise emotional expression and limit information transmission and accuracy. In the future, more precise transmission methods could be employed, such as haptic gloves offering vibration, force feedback, thermal feedback, and motion recognition, or introducing olfactory wearable devices to be used alongside immersive equipment to more comprehensively meet emotional transmission needs [28, 34, 36]. Rather than assuming users' physical abilities, familiarity with technology and capacity to interpret emotional signals and multi-sensory simulations/responses based on their age [7] or background, users could first establish a baseline, select tutorials tailored to their familiarity with XR, haptics, and olfactory devices (e.g., never used, familiar, or proficient), ensuring relevant training and simulation preferences, and avoiding stereotypes.

It is also proposed to conduct a series of co-design workshops with expert XR designers to inform the follow-up iterations of the application to explore potential multimodal interactions engaging with haptic, thermal and olfactory simulations. The objective would be to identify both the affordance of each simulation technology, as well as assess the feasibility of their implementation. As a result, products may become more engaging, leading to more affluent and meaningful user interactions. With the development of GenAI, communication efficiency in immersive spaces can be further enhanced. For example, GenAI can assist users by generating 3D objects, images, and spatial effects efficiently, enabling the transformation of 2D photos into immersive scenes[15, 16].

The findings of the study suggest that single-modal visual or auditory long-distance interactions may not fully meet the needs of emotional transmission. Although converting biological signals into long-distance tactile non-verbal interaction via smartphone vibrations can partially compensate for this, such methods lack precise emotional expression and limit information transmission and accuracy. In the future, more precise transmission methods could be employed, such as haptic gloves and haptic suits [35] offering vibration, force feedback, thermal feedback, and motion recognition, as well as introducing olfactory wearable devices to be used alongside immersive equipment to more comprehensively meet emotional transmission needs [28, 34, 36].

Non-real-time communication can also enhance emotional connections by allowing users to reconnect with past emotions and experiences through immersive memory spaces. This approach fosters consistency in virtual interactions and strengthens relationships by promoting mutual reminiscence, creating a sense of belonging and closeness from past interactions. We propose designing an online memory space where shared objects and data between partners can be stored, customised and shared. This approach can further support non-verbal communication and spatial interactions supporting both real-time and asynchronous activities. In this scenario, users could access this space through head-mounted devices to revisit immersive spatial experiences from the past using XR headsets and mobile applications.

Finally, rigorous short-term and long-term well-being assessments should be conducted to evaluate the impact on user well-being in both laboratory and home environments[36]. In laboratory settings, tools such as the PANAS scale [29], facial expression analysis, eye-tracking, and EEG can be utilized to precisely monitor participants' emotional fluctuations [4, 20]. For long-term emotional monitoring in everyday environments, non-invasive methods such as the WHO-5 Well-being Index and semi-structured periodic interviews can be employed. This approach facilitates tracking changes in user well-being, particularly in relation to the long-term effects of interventions or significant life changes [33].

8 CONCLUSIONS

In this paper, we investigate the potential and problems of nonverbal communication and spatial interaction systems in long-distance relationships to enhance intimacy between remote partners. This study uses the power of immersive social systems, haptic feedback, emotion recognition, and spatial computing to bridge the separation that characterizes long-distance couples. Incorporating emotional and social data into visualizations shapes responsive, socio-enjoyable experiences with unique potential for rich, personalized sociability opportunities. The study's key findings suggest that non-verbal communication and spatial interaction can boost intimacy and social connections for some long-distance couples. This underscores the potential of using biological signal visualization, spatial virtual objects, and non-verbal emotional expression to address the limitations of emotional transmission, weak information acquisition, and monotonous communication that often plague traditional long-distance relationships.

Although this study demonstrates the potential value of spatial and non-verbal communication in enhancing the interaction and intimacy of long-distance couples, it is limited by sample representativeness and the experimental environment. Future research could incorporate differentiated design methods by expanding the diversity of scenarios, periods, and testing across different age groups. Introducing multimodal emotional transmission and non-real-time memory spaces could enhance users' emotional experience and well-being. Our work provides preliminary methods, experiences, and practical insights for long-distance multimodal immersive interaction, offering new perspectives and application avenues for future development.

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A APPENDIX

A.1 Part One

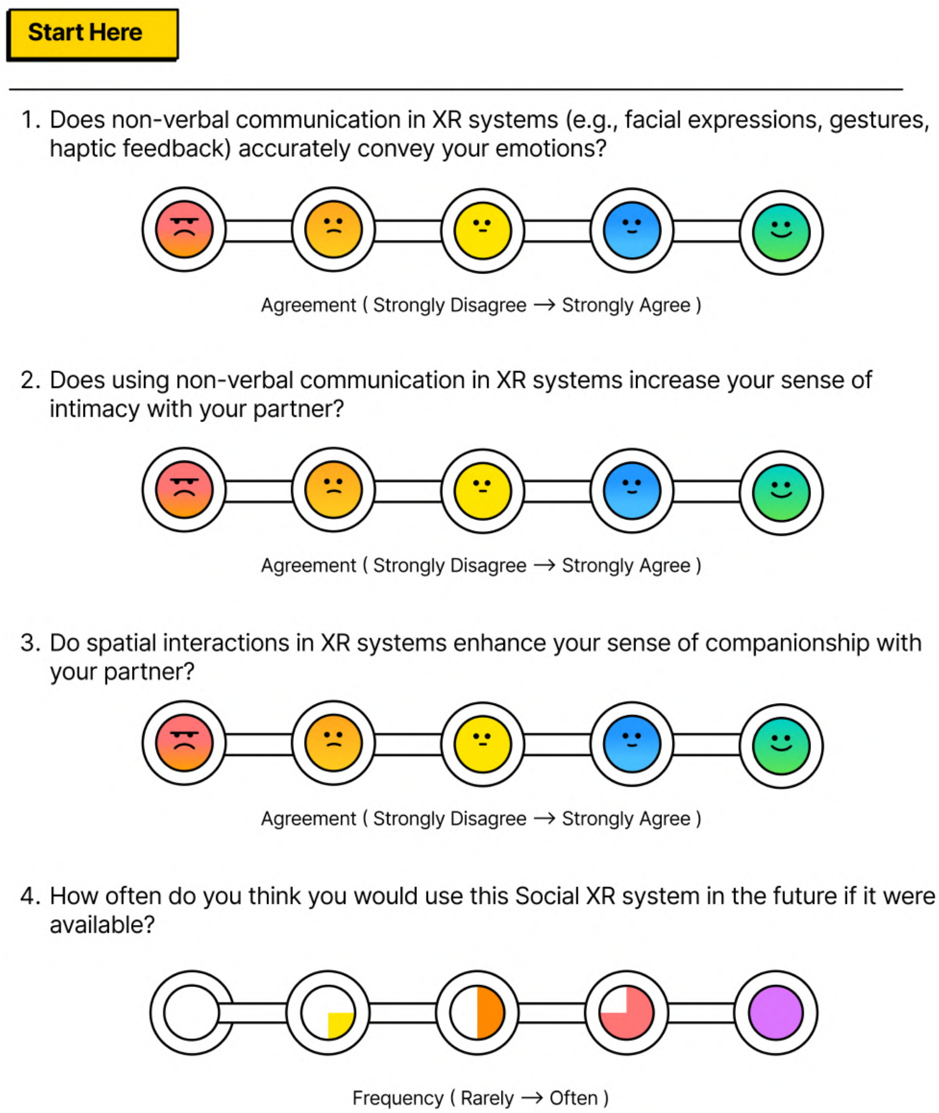

Fig. 9. User Experience Assessment: Evaluating Non-Verbal Communication and Spatial Interaction in XR Systems Using Likert Scale.

A.2 Part Two

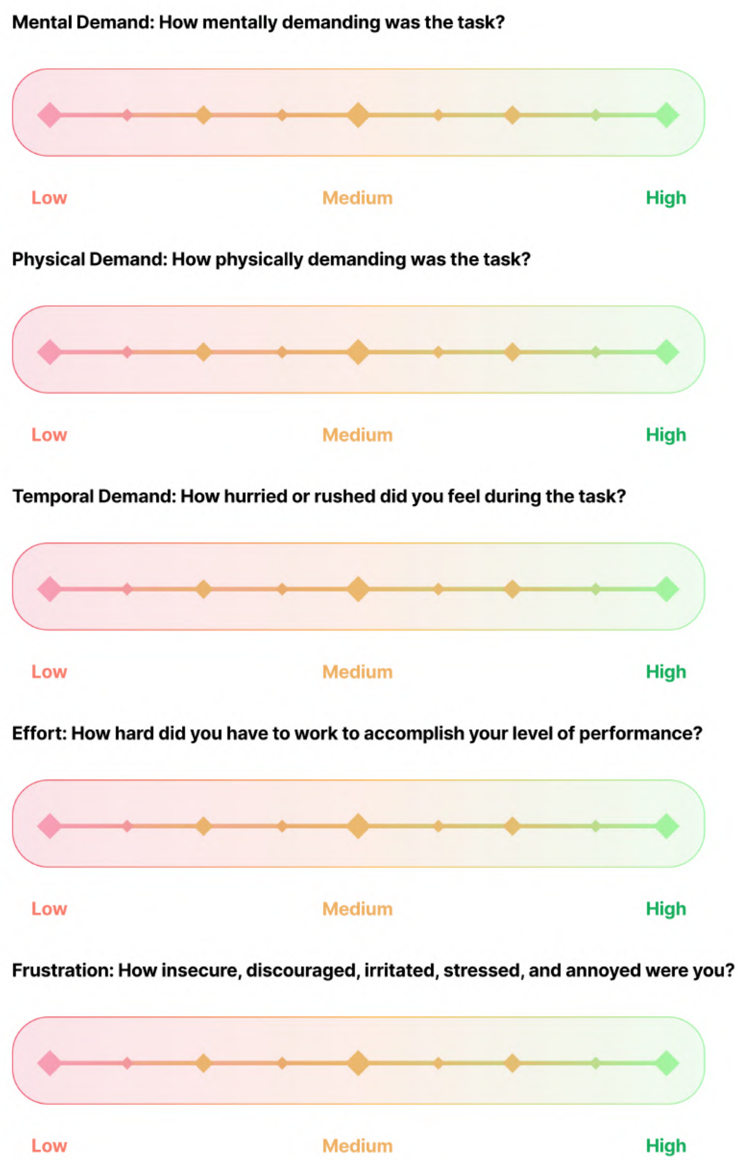

Fig. 10. Task Load Assessment Questions (Based on NASA-TLX).