Designing Socially Adaptive XR for Exposure Therapy: Telepresence, Personalization, and Real-Time Environmental Modulation

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Abstract

Exposure therapy is effective for anxiety-related conditions; however, traditional in vivo approaches often lack controllability and scalability. We present TRUST-XR, a socially adaptive extended reality (XR) system that integrates therapist telepresence with real-time environmental modulation to support structured exposure therapy. The system implements three adaptive scenarios targeting social anxiety, claustrophobia, and acrophobia, dynamically adjusting social density, spatial constraints, and elevation cues based on therapist input and user responses. Therapists are embodied as holographic avatars within the immersive environment, enabling continuous guidance and scenario adaptation. We report findings from a small-scale formative study evaluating user experience, perceived safety, and preliminary therapeutic outcomes. TRUST-XR contributes a socially adaptive XR framework for therapeutic applications and demonstrates how social XR principles can support confidence-building interventions in controlled clinical contexts.

Keywords

adaptive XR, exposure therapy, social augmentation, therapist telepresence, immersive environments, mental health, social anxiety, claustrophobia, acrophobia, human-computer interaction

1. Introduction

Many people experience discomfort in crowded public spaces, confined spaces, or at elevated heights. These experiences, which are typically associated with fears and stressful conditions like social anxiety, claustrophobia, and acrophobia, can limit participation in everyday life and negatively impact confidence and well-being. Exposure-based therapeutic approaches are widely recognized as practical interventions; however, traditional in vivo exposure can be limited by logistical constraints, ethical considerations, lack of controllability, and difficulties in reproducing exposure intensity levels in real-world environments.

Extended Reality (XR) technologies provide a promising alternative by allowing safe, controlled, and repeatable simulations of anxiety-inducing situations. Beyond replicating real-world scenarios, XR environments can be dynamically modulated, enabling fine-grained control over spatial, visual, and social parameters. These capabilities offer new opportunities for *social augmentation*, in which environmental cues and relational dynamics are intentionally shaped to support emotional regulation, resilience, and therapeutic engagement.

Through TRUST-XR, we present an adaptive therapeutic XR system that integrates real-time environmental modulation with therapist telepresence to support structured exposure therapy. The system implements progressively adjustable scenarios targeting social anxiety, claustrophobia, and acrophobia, where environmental complexity can be modified dynamically. Therapists are represented as avatars within the immersive environment and can observe, intervene, and adjust scenario parameters

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through a dedicated control interface, ensuring responsiveness and emotional safety throughout the session.

This work contributes a socially adaptive XR framework for exposure therapy that integrates therapist telepresence and real-time environmental modulation, positioning therapeutic XR within the broader social XR research agenda. This contribution is operationalized through three implemented exposure scenarios, which demonstrate how social and environmental variables can be systematically structured and dynamically controlled. Additionally, we report findings from a small-scale formative user study evaluating user experience, perceived safety, and preliminary therapeutic outcomes.

2. Related works

Recent research demonstrates that immersive XR can effectively support exposure therapy; XR environments allow controlled replication of real-world stressors while offering repeatability and progressive scaling [1, 2]. Compared to traditional in vivo exposure, XR enables fine-grained control over environmental variables and reduces ethical and logistical barriers. Research has shown promise in treating claustrophobia [3], agoraphobia [4], and other anxiety-related disorders. XR also supports gradual desensitization and emotional regulation through immersive engagement and embodied interaction [5]. However, many existing systems rely on static scenario scripting, limiting real-time personalization and therapist interaction.

Adaptive XR systems dynamically modify environmental parameters in response to user behavior, physiological inputs, or therapist intervention. Personalization improves inclusivity and therapeutic alignment by accommodating varying tolerance levels and psychological profiles [6]. However, most adaptive XR systems emphasize individual interaction rather than socially mediated adaptation. In therapeutic contexts, personalization often involves pre-session configuration rather than real-time adjustment. TRUST-XR extends this approach by enabling dynamic modulation of environmental and social variables during exposure sessions.

In this direction, telepresence technologies enable remote co-virtually-located interaction within immersive environments. In therapeutic contexts, XR-based interventions have shown potential to enhance communication and emotional support [7]. Representing therapists as avatars/holograms within XR spaces strengthens relational presence and supports collaborative engagement. Within the broader social XR paradigm, systems aim to augment social cues (e.g., gaze, spatial proximity, or emotional signals) to enhance communication and trust. However, limited work has explored how social augmentation can be integrated into therapeutic exposure contexts where emotional regulation and safety are central.

3. Conceptual framework: design, scenarios, and first results

TRUST-XR is grounded in a socially adaptive therapeutic XR framework that integrates real-time environmental modulation with therapist telepresence. The framework positions exposure therapy as a form of socially augmented interaction in which immersive environments, relational presence, and adaptive control operate in a continuous feedback loop. In this section, we briefly discuss the system design, the implemented scenarios, and a small-scale formative user study.

3.1. System design

Considering that TRUST-XR combines XR environments with therapist telepresence and dynamic scenario adaptation, the design is based on five core features:

- **Adaptive scenario progression.** Each XR scenario dynamically adjusts visual, auditory, and spatial parameters based on user state and therapist input. For example, crowd density may increase gradually in a social anxiety scenario, lighting conditions may shift in confined spaces, and elevation transparency may be modified in height exposure. These adaptations allow fine-grained modulation of perceived challenge while maintaining therapeutic safety.

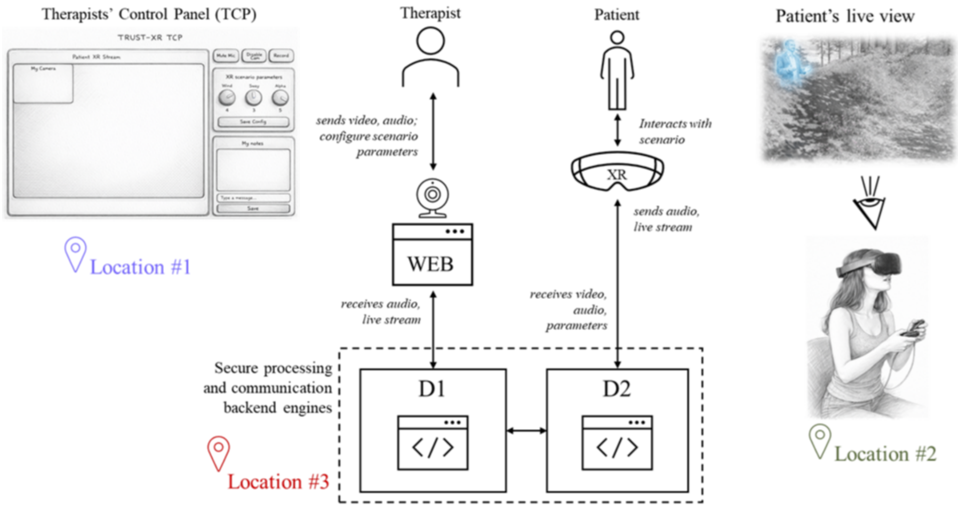

Figure 1: Conceptual architecture of TRUST-XR across distributed locations. The therapist operates the TRUST-XR Therapist Control Panel (TCP) at Location #1, dynamically adjusting scenario parameters and monitoring the patient's XR stream. The user engages with the immersive environment at Location #2 through a head-mounted display. System components coordinate adaptive rendering and real-time communication across infrastructure nodes (Location #3), enabling low-latency telepresence and therapist-in-the-loop environmental modulation.

- **Therapist holographic guidance.** Therapists are represented in the XR environment through holographic avatars. The therapist avatar is streamed in real time via a networked telepresence pipeline that combines voice communication and avatar embodiment, synchronized with the XR environment. Using low-latency communication channels, they can guide users in real time, observe behavioral responses, intervene when necessary, and modify environmental parameters through a dedicated control dashboard. This design transforms exposure from an isolated experience into a socially scaffolded interaction.
- **Personalized exposure tasks.** Each scenario includes task-based objectives tailored to individual therapeutic goals (e.g., purchasing a train ticket, navigating to a platform, selecting elevator floors, walking across a skybridge). These structured activities promote engagement, reinforce agency, and support goal-oriented therapy rather than passive exposure, encouraging gradual confidence building and helping users actively engage with anxiety-inducing situations in a controlled therapeutic progression.
- **Minimal spatial requirements.** The system is designed for confined deployment environments. Users can participate in a standing or seated configuration without requiring physical locomotion across large spaces. This enables deployment in clinics, schools, and research laboratories, increasing accessibility and scalability, while reducing infrastructure constraints and enabling flexible installation within typical therapeutic or research settings.
- **Live spectator view.** The setup includes an external monitor that mirrors the user's XR perspective, allowing therapists and researchers to monitor the session in real time and facilitating post-session reflection and collaborative discussion. This feature further reinforces the social dimension of the therapeutic experience, supporting shared understanding of user reactions and enabling more informed therapeutic feedback and session evaluation.

The aforementioned design principles establish TRUST-XR as a socially adaptive system in which environmental cues, relational presence, and user state continuously inform each other. Figure 1 presents the conceptual architecture of TRUST-XR. In addition to its functional architecture, we note that

TRUST-XR incorporates security and compliance validation through integration with the CONSOLE cybersecurity platform, which embeds within the system's development and deployment pipeline to support automated static and dynamic analysis across the platform's multi-language software stack, including Unity/C#, Python microservices, and real-time communication components. Through this integration, the system benefits from continuous vulnerability detection, dependency monitoring, and compliance validation aligned with European regulatory frameworks such as GDPR and the Cyber Resilience Act. This approach supports secure-by-design development practices and strengthens the reliability and trustworthiness of XR-based therapeutic systems that process sensitive behavioral and psychological data.

3.2. Therapeutic scenarios

Building upon the design principles discussed in the previous section, TRUST-XR implements three adaptive exposure scenarios (Figure 2). Across all three scenarios, TRUST-XR operationalizes socially adaptive therapeutic XR through: (i) dynamic modulation of environmental and social stimuli, (ii) therapist-in-the-loop control and telepresence, and (iii) task-driven interaction promoting agency and structured engagement. Collectively, these scenarios demonstrate how immersive environments can move beyond static exposure and function as socially intelligent systems that enable emotional regulation, trust, and confidence within controlled therapeutic settings.

3.2.1. Facing fear of crowded spaces (agoraphobia)

This scenario is designed to address social anxiety and agoraphobia by gradually increasing exposure to socially dense environments. The user begins in a calm virtual train station with minimal background activity. The first task involves locating and purchasing a train ticket using a simple hand-based interface. As the task progresses, animated avatars representing other passengers enter the space, gradually increasing social presence. Ambient audio simulating station announcements and crowd murmur intensifies gradually. The second task requires navigating through the station to reach a designated platform, interpreting signage, and choosing between alternative paths. Spatial bottlenecks and proximity to virtual characters introduce mild social stressors. Dynamic adaptation enables real-time adjustment of crowd density, avatar movement patterns, and audio intensity in response to user state and therapist intervention. A mild controlled disruption (e.g., an invalid or lost ticket) may be introduced to encourage problem-solving interaction with a virtual help desk agent. This scenario aligns with social XR principles by demonstrating how social cues (e.g., presence, proximity, environmental noise, and interaction complexity) can be augmented and modulated to scaffold confidence and emotional regulation while maintaining therapist-supported safety.

3.2.2. Overcoming spatial confinement (claustrophobia)

This scenario focuses on gradual exposure to confined environments. The experience begins in a spacious, calming VR lobby where the user acclimates and engages in light interaction with the therapist. When ready, the user enters a virtual elevator that initiates a controlled transition into a more confined space. The elevator's dimensions, lighting conditions, ride duration, and ambient sound cues are dynamically adjustable in real time. Throughout the ride, collaborative tasks (e.g., selecting a destination floor, engaging in calming mini-games) redirect attention and reinforce engagement. Therapist telepresence ensures immediate responsiveness to signs of distress and allows fine-grained modulation of environmental parameters. This scenario reflects socially adaptive XR by integrating relational presence with environmental modulation. The therapist's holographic embodiment serves as a stabilizing social anchor, reinforcing emotional safety while controlled spatial constraints gradually increase psychological challenge.

(a) (b) (c)

Figure 2: Each scenario supports gradual user engagement through immersive, personalized tasks: (a) dynamic social spaces simulate increasing social density in a public setting; (b) spatial confinement progression introduces adjustable spatial constraints in a virtual elevator environment; and (c) elevated perspective exploration allows controlled exposure to vertical settings via a semi-transparent skybridge

3.2.3. Building confidence with heights (acrophobia)

This scenario places the user on a semi-transparent skybridge suspended over a scenic landscape. The initial exposure begins at a modest elevation with limited transparency. Over time, elevation, bridge transparency, and environmental depth cues are progressively increased. Task-based objectives include collecting virtual tokens and reaching designated lookout points; they encourage movement and engagement without overwhelming the user. The therapist provides continuous encouragement and can manually adjust intensity parameters or adjust them based on observed behavioral cues. Optional integration of self-reported anxiety input further supports adaptive modulation. This scenario demonstrates how immersive spatial cues can be carefully structured to balance vertical immersion with therapeutic safety. By combining environmental adaptation with real-time relational support, it aims to support incremental resilience and confidence-building.

3.3. User study

To explore the feasibility and experiential qualities of TRUST-XR, we conducted a small-scale formative study with five participants and one therapist. The study focuses on the height-exposure scenario as an initial exploratory evaluation of the system's interaction design and therapist-in-the-loop adaptation. All participants engaged in an individual exposure session, guided by the therapist through the telepresence interface. Following the session, participants took part in a structured brainstorming discussion (in a focus group format), while the therapist provided separate reflective feedback on system use. This exploratory evaluation should be interpreted as a formative study aimed at understanding experiential qualities and therapist usability rather than providing clinical evidence of therapeutic effectiveness.

3.3.1. Procedure

Each session followed a milestone-based exposure progression. Participants were instructed to verbalize their thoughts and feelings throughout the experience using a think-aloud protocol. The therapist dynamically adjusted environmental parameters (e.g., elevation, transparency, wind intensity) in response to participant reactions. After completing the scenario, participants joined a post-session discussion to reflect on immersion, emotional regulation, usability, and perceived safety.

3.3.2. Think-aloud insights

The think-aloud protocol revealed intense immersion and emotional engagement. Participants frequently commented on the realism of the height simulation. One noted, *"for a moment I forgot I was in* *a room ... my stomach actually dropped"*, highlighting the embodied impact of vertical depth cues. In this direction, the structured progression of milestones supported emotional regulation. Participants described a sense of control as exposure intensified incrementally rather than abruptly. However, moments of visual overload were reported when looking down through transparent surfaces. One participant stated, "I needed a second to breathe because the drop looked too real." Moreover, the therapist's presence played a critical grounding role. Participants emphasized that continuous verbal guidance enhanced their sense of safety: "The therapist's voice kept me calm… I trusted that they wouldn't push me too far." These responses suggest that immersion and adaptive support operated together to create a controlled yet emotionally meaningful exposure trajectory.

3.3.3. Therapist experience

The therapist reported high perceived control over the exposure process through the Therapist Control Panel (TCP). The interface was described as "intuitive and responsive; everything I needed was at my fingertips." Real-time adjustment of sway, wind intensity, and transparency allowed fine-grained titration of anxiety levels based on both verbal and non-verbal cues. Moreover, the live spectator view enhanced situational awareness, while integrated voice communication supported connection and emotional regulation. The therapist identified potential improvements, including preset difficulty profiles (e.g., mild, moderate, intense), a visible milestone progress indicator, and integration of physiological signals such as heart rate. These additions were seen as opportunities to further support evidence-based personalization.

3.3.4. Post-session reflections

The focus group discussion revealed a strong consensus that TRUST-XR provided a compelling yet safe experience. Participants described the system as allowing them to "take risks I would never take in real life" while still feeling protected. A consistent theme was meaningful emotional progression across milestones, from curiosity to controlled anxiety to mastery upon task completion. Moreover, immersion was frequently linked to depth perception and environmental realism. Usability impressions were positive, with participants noting that the interaction flow "just made sense." Suggested improvements included an optional tutorial space, greater environmental variation (e.g., ambient soundscapes), and a post-session reflection screen summarizing progress.

3.3.5. Summary of findings

Overall, findings from this small-scale formative user study indicate that combining adaptive environmental modulation with therapist-in-the-loop telepresence can: (i) enhance perceived immersion and emotional realism, (ii) support structured and manageable anxiety progression, (iii) reinforce trust and safety through relational presence, and (iv) provide therapists with precise control over exposure intensity. While preliminary and exploratory, these results suggest that socially adaptive XR systems such as TRUST-XR can effectively balance psychological challenge with emotional safety, aligning with core principles of exposure therapy and social XR design.

4. Discussion

4.1. Contribution and implications

This paper contributes to the workshop's agenda on social XR by framing exposure therapy as a form of socially adaptive augmentation. TRUST-XR demonstrates how environmental modulation and therapist telepresence can operate as coordinated mechanisms for emotional scaffolding within immersive environments. Rather than treating XR as a standalone simulation tool, we position it as a socially mediated system in which relational presence and adaptive control shape the user experience. In this sense, TRUST-XR illustrates how socially augmented XR environments can move beyond static simulation toward interactive therapeutic ecosystems that dynamically balance challenge and psychological safety.

The preliminary study findings suggest that combining real-time environmental adjustment with therapist-in-the-loop interaction strengthens perceived safety, trust, and engagement. Participants' reflections indicate that the therapist's presence serves as a stabilizing social anchor, enabling users to engage with increasingly challenging stimuli while maintaining a sense of emotional support. This highlights the importance of relational grounding in therapeutic XR experiences, particularly when users confront anxiety-inducing scenarios.

Implications for social XR design include: (i) integrate adaptive control with clear milestone progression to maintain user agency; (ii) preserve continuous relational grounding to support emotional regulation; and (iii) provide therapists with transparent, responsive control interfaces. Together, these principles suggest that socially adaptive XR systems can function as collaborative therapeutic spaces where environmental cues and human guidance jointly shape user experience. These lessons highlight the value of designing socially intelligent XR systems that balance challenge with psychological containment. They also emphasize the importance of secure-by-design XR infrastructure that ensures data protection, system reliability, and regulatory readiness when immersive technologies are applied in sensitive healthcare contexts.

4.2. Limitations and future work

We note that our work introduces limitations that include (i) a small sample size, which restricts generalizability; (ii) a focus on a single scenario in the empirical evaluation; and (iii) the absence of quantitative physiological measures to complement qualitative insights. Future work will increase sample size, evaluate varying scenarios under controlled conditions, and integrate biometric signals to support evidence-based adaptation. Future research could also explore semi-automated scenario adaptation using behavioral or physiological cues, as well as group-based or peer-mediated exposure scenarios that extend socially adaptive XR beyond therapist–patient dyads. We also plan longitudinal studies to examine sustained therapeutic impact and investigate how perceptions of trust and social presence evolve across repeated XR therapy sessions.

5. Conclusion

In this extended abstract, we presented TRUST-XR, a socially adaptive XR system that integrates therapist telepresence with real-time environmental modulation to support structured exposure therapy. Through adaptive scenarios, the system demonstrates how immersive environments can function as socially intelligent therapeutic spaces. Findings from a small-scale formative study indicate that combining adaptive environmental control with therapist-in-the-loop guidance enhances immersion, trust, and perceived safety while maintaining structured emotional progression. By aligning exposure therapy with principles of social XR, this work extends current XR therapy approaches toward relationally grounded and dynamically responsive systems. TRUST-XR contributes design insights for developing socially adaptive XR applications that balance psychological challenge with emotional containment in sensitive domains.

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Declaration on Generative AI

The authors have not used any Generative AI tools.

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