# LabXscape: A Prototype for Enhancing Player Experience in Cross-Reality Gameplay


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## Abstract

Interest in multiplayer games that allow players to connect and play together using different technologies, such as virtual or augmented reality (VR/AR) has increased. Research has shown that in cross-reality gaming experiences (eg. where there are differences in players' abilities, user interface (UI), and methods of interaction) it is possible to achieve an enhanced player experience (PX) through various interdependencies. However, most of the previous work focuses on co-located scenarios, where the space and proximity of the players are local and utilized. In this study we present a cross-reality prototype called LabXscape. Through the prototype we are researching how asymmetries of space, UI, methods of interaction, information access, and narrative impact the PX for players using different technologies (eg. VR, AR, PC). In this cross-reality prototype, players can connect with different devices found on the Milgram and Kishino's Reality-Virtuality Continuum. Their interactions, movements, and information influence and are shared with each other, creating a cross-reality experience. Our observations reveal that there are factors that allow non-VR players to have as engaging experience as VR players, despite using a less immersive device.



**Keywords**: Virtual reality, mixed/augmented reality, gameplay, narrative, multiplayer, asymmetric, cross-reality


## 1 Introduction

A recent surge in interest in technology that allows people to connect, play, and collaborate, can be attributed to the physical restrictions imposed by the pandemic. A technology area that has seen growth during the pandemic is multiplayer games [1]. Immersive technologies such as VR and AR have also seen an increase in adoption, as people were looking for ways to connect during the lockdowns and beyond [2]. Despite their immersive qualities, head mounted displays (HMDs) have received criticism for their isolating characteristics, both socially and technologically [3] and for the discomfort they sometimes induce [4]. As a result of these limitations, VR research and design has started to look more and more into leveraging different systems for the design of novel interactions, which include bystanders and co-players. In this context, various types of asymmetries were considered from the asymmetry of player interfaces (rooted asymmetric multiplayer VR is relatively novel with only 25 relevant papers identified by a recent systematic review conducted by Rogers et al. [5], which proposes a framework based on the types of asymmetries designed in multiplayer VR games and on their impact on the PX. The authors identified a set of opportunities for future work such as asymmetric VR games with more than two players, alternative interfaces, mirrored and unidirectional interdependence between players, remote play, or the need for more investigation of the social factors of player experience. With this study, our aim is to address some of these existing gaps by developing an asymmetric VR game that connects remote VR, AR, and PC users in a shared virtual environment. The prototype application will be designed following the best practices recommended in [5], [6], [7], and [8]. This work-in-progress paper focuses on the workflow process of the development of the cross-reality game and provides some initial observations.

## 2 Related Work

Asymmetric gameplay in VR games has had significant research and development over the years [5]. Pereira et al. [7] provide guidelines when designing asymmetric interactions. The importance of interdependence in cross-reality games is validated by Karaosmanoglu et al. [8], who found interdependencies created positive social interactions between players and increased player enjoyment. Smilovitch and Lachman [9] developed an asymmetric game that focuses on interdependence and communication, with the primary method of communication being gestural. Piumsomboon et al. [10] included in their research a collaborative interaction requiring both participants to interact with an object to reveal hidden information, which can reinforce social presence. Olin et al. [11] researched cross-device collaboration and social interactions in VR. With the mobile device, locomotion was limited to on-screen interactions for artificial locomotion. According to [12], physical movement allows users to better remember what they encounter and be more immersed. Some of the related works have informed the design of the cross-reality prototype, while others have uncovered research gaps.

### 2.1 Research Gaps

In their extensive systematic review of asymmetric gameplay in multiplayer VR games, Rogers et al. [5] identified a number of gaps and opportunities. In existing studies, players are often co-located, which can heavily increase social presence. Co-located experiences are not always practical and can reduce the number of people who can play the game. Understanding how remote setups would influence the different aspects of PX was highlighted as an important direction as this creates new possibilities for increasing access by allowing people from around the world to connect and play together, despite physical distance. Therefore, with our prototype we explore the challenges and affordances brought by space asymmetry in communication and social presence, and the impact on PX. PX in cooperative asymmetric VR games is greatly influenced by team dynamics and communication, but very few studies addressed this factor. According to [13], player experience is shaped by mechanics (the "rules of the game and interaction options), context (the device that is used, the physical setting, presence of others), and narrative (the story, plot, events, and characters). Unfortunately, player experience as it relates to narrative were not included in any of the papers reviewed in [5].


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In this paper we attempt to answer the following questions:

- **RQ1:** What factors affect PX in a remote cross-reality game?
- **RQ2:** How is PX affected by the embodiment and interaction limitations and affordances of VR, AR, and PC devices?

Preliminary findings on these questions will be presented in this paper, but a more detailed analysis will be published later.

## 3 System Design

To answer our research questions, we have designed and developed *LabXscape*, a cross-reality escape room experience where remote players cooperate using different technologies. To understand how the limitations and affordances of different technologies impact the PX, we implemented interactions for VR, AR, and PC. The affordances and limitations of each device have been considered when developing the cross-reality prototype game.


Figure 1. The virtual environment in LabXscape

The game is a narrative-based experience where the players work together to prevent a catastrophic meltdown in a laboratory. The VR player has the role of the scientist; ultimately responsible for preventing the meltdown. The VR player cannot accomplish their goals without support from the other players. The AR player has the role of the robot that that supports the VR player, but unlike other studies [7, p. 11], the AR player has an active role which requires movement and interacting with the environment. The position and rotation of the AR player is based on the physical movement and rotation of the mobile device, resulting in the device acting as a window into the virtual environment. Due the potential of limited physical space, artificial locomotion has been included for both the VR and AR players. As the AR player looks around and moves through the virtual environment, their movement is synced and shown in real-time to the VR and PC players. The PC player is in a security office observing the VR and AR players through security cameras. They are the holder of information on how the VR player can prevent the meltdown, but the information that they share will be based on what the VR and AR players see in the virtual environment. This asymmetry of information is called the hidden profile paradigm [14] and creates interdependencies. Each player is physically separated and can only communicate through the game.

Each device has an avatar that creates a sense of embodiment and social presence. The VR player's avatar has full motion tracking and auditory and visual feedback when they talk (see Figure 1a). While the PC player does not have an avatar in the traditional sense, the sense of social presence for others is created as they scan and communicate through the security cameras. When the PC player rotates the cameras, this is seen and heard by the other players. When they are viewing through a particular camera, the red "record" light is on (see Figure 1b). The AR player's avatar is a hovering robot, which plays to the absence of hand-tracking on a mobile device. When the AR player talks, the others can hear and get visual feedback in the form of a light blinking (see Figure 1c). In both cases, the PC and AR players are not present in the virtual space, but through their devices are acting as a window into the virtual environment. This window is fits with the narrative, leverages the limitations of the devices, and ultimately draws the player into the experience.

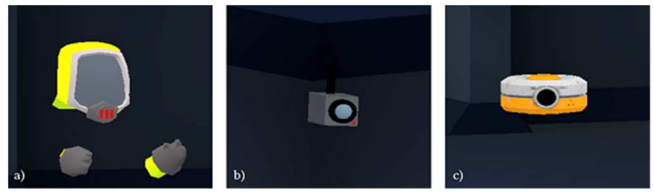



Figure 2. Visual representation of players using different devices. VR player (a), PC player (b), and AR player (c).

Task 1: Exit the Correct Door: There are multiple doors to choose from, but only one is correct. This task creates multiple interdependencies, which will foster communication and enhance social presence. The first interdependency is based on the hidden profile paradigm. Only the PC player can determine which door is correct by toggling through the various security cameras. This task could be completed without involvement from the PC player, but potentially slower. This type of dependency is called unidirectional dependence [7, p. 12]. The second interdependency occurs between the VR and AR players. Interactions are required by both players to unlock each door.

Task 2: Prepare the Reactor: There are several levers and buttons that the VR player needs to interact with. The PC player has a list of possible configurations. The correct configuration depends on the color the force field and reactor. This information is only available to the VR and AR players and needs to be communicated to the PC player. While the VR player could attempt to adjust the levers and buttons without support from the PC player, it is virtually impossible to guess the correct configuration. When the levers and buttons are done correctly, the reactor shield and glass are lowered, which can be confirmed by the AR player.

Task 3: Replace the Power Crystal: There is a cabinet with several colored crystals to choose from, but only one crystal is correct. The color of crystal is dependent on the color of the reactor, which can be shared to the PC player by the VR or AR players. Then the PC player can share which color of crystal to use, but the AR player needs to scan the crystal to identify specifically which one to use. In addition, the cabinet is locked and the code to unlock can only be seen by the VR or AR players, but the act of unlocking is done by the PC player. These interdependencies foster team communication and enhance social presence as the players as complete tasks together.

## 4 System Implementation

The game was developed using the Unity game engine (version 2020.3.9) with the following additional packages: XR Interaction Toolkit (VR) AR Foundation (AR), and Normcore (multiplayer). The VR device setup used an Oculus Quest 2 standalone device. The AR device setup used a Lenovo P11 Plus 11" tablet. The PC device setup used a Dell computer with a NVIDIA 2070 Super GPU and a 27” monitor. All players used over-the-ear headphones for spatialized audio and to improve immersion.

Players can verbally communicate with each other, despite virtual distances. Interaction and feedback sound effects are spatialized, which means that if a player does an interaction that causes a sound effect to be played as a response, only the player that is near the source of the sound will hear it.

## 5 USER STUDY

The goal of this study is to determine how PX is affected when three players participate, each with a device with different affordances and limitations, in a remotely located cross-reality game. The study was conducted with 24 participants. They participated in groups of three and each player was assigned a device/role (AR/VR/PC) using a simple random sampling approach. [15].

### 5.1 Methodology

A mixed methods research design was used for the study, with the device (VR, AR, PC) as the independent variable. Sessions were recorded for participant observation to identify non-verbal cues, such as facial expressions, as well as team dynamics, communication, and performance. Additional information on player experience that may not be volunteered during the other data collection methods can be gained during observation [16].

Following each gameplay session, each participant completed a survey which was a combination of a short version of the Game User Experience Satisfaction Scale (GUESS-18) [17] and the social presence subset of the Multimodal Presence Scale (MPS) [18]. The GUESS-18 is 18-item tool, with items being rated with a 7-point Likert scale (1 = Strongly Disagree to 7 = Strongly Agree). The total value in the GUESS-18 tool is 60. The social presence subset of the MPS consists of 5 items, with each item rated with a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The total value of the social presence subset of the MPS is 25.

After the survey, a short semi-structured interview was conducted.

### 5.2 Participants

The study was conducted with 24 participants (15 male, 9 female) with the majority (37.5%) in the 35 – 44 age range. 87% of PC players were familiar or very familiar with computers, 50% of AR players had used AR 10 times or more, and 50% of VR players had used VR 10 times or more.

## 6 RESULTS

A statistical analysis of the quantitative data has been completed and a comprehensive thematic analysis is currently in progress.

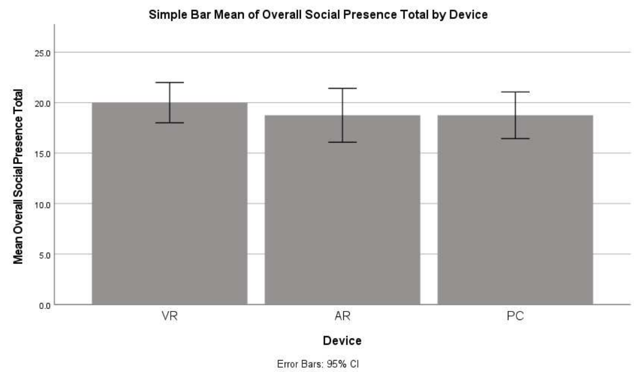
### 6.1 Quantitative Results

#### 6.1.1 Player Experience (GUESS-18)

There are a numbers affecting video game satisfaction including engagement, immersion, and presence. The GUESS-18 tool is used to identify “the degree to which the player feels gratified with his or her experience while playing a video game” [19].

A one-way ANOVA was conducted to determine if player experience (overall GUESS-18 score) was different for groups using different types of devices to access the cross-reality game. The ANOVA results showed no statistically significant difference between the three device groups, $F (3, 21) = .762$, $p = .479$. Data is presented as mean ± standard deviation. VR players’ satisfaction ($M = 51.2$, $SD = 4.6$) was very similar to PC players’ satisfaction ($M = 50.0$, $SD = 10.4$), but AR players’ satisfaction ($M = 46.5$, $SD = 9.5$) was slightly lower.

Figure 3. Visual representation of the overall GUESS-18 scores




#### 6.1.2 Social Presence

Social presence, which is described as the feeling of being there with a “real” person [20], has been found to be significant factor affecting PX [21].

Another one-way ANOVA was conducted to determine if social presence was different for groups using different types of devices to access the cross-reality game. The ANOVA results showed no statistically significance between the three device groups, $F (3, 21) = .530$, $p = .596$. Data is presented as mean ± standard deviation. VR players experienced slightly higher social presence ($M = 20$, $SD = 2.4$). PC players ($M = 18.7$, $SD = 3.2$) and AR players ($M = 18.7$, $SD = 2.8$) experienced similar levels of social presence.

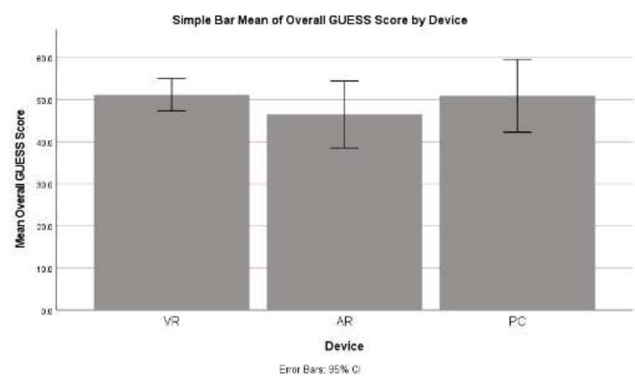



Figure 4. Visual representation of the social presence totals

### 6.2 Qualitative Results

A preliminary thematic analysis has been conducted on the interview transcripts and video observations for the 24 participants. The key findings from the preliminary thematic analysis include:

- The hidden profile paradigm [14] created interdependencies between players, which fostered team communication and improved PX.
- Interactions and locomotion mechanics that leverage device limitations and support the narrative had a positive effect on PX.
- Anthropomorphic avatars for all players will improve social presence.
- Narrative and role had a positive effect on PX, motivation, and engagement.

These findings are highlighted by these participant quotes:

- "Even though I was in here *[referring to a computer lab],* I completely disengaged from most of it. I'm lucky I didn't run into one of the computers." – AR player
- "I also have a vivid imagination, so putting myself into a security officer role. I can just go for it." – PC player

## 7 Discussion and Next Steps

Cross-reality multiplayer games is a growing industry. Non-VR players can have similar engaging PX as VR players. A primary factor affecting PX is the narrative and role, but specifically, roles and interactions that reflect the affordances and limitations of each device. As a result of this research, the intent is to develop a best practices document for developing remote cross-reality multiplayer games and experiences. This document will provide insights into avatar, environment, interaction, and narrative considerations required to improve PX in cross-reality multiplayer games.

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